FORALPS

High quality climate data for the assessment of Alpine climate, its variability and change on regional scale - Collection and analysis of historical climatological data and metadata

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1. Motivation

Mankind is currently experiencing a significant change of one of the most important factors controlling general living conditions on our planet – climate change. This climate change is partly anthropogenic. A quantification of the human factor influencing this shift in global climate is difficult to quantify for the past, present and the future. This is particular true if the natural multi-timescale variability of climate is taken into consideration as well. To study Alpine Climate and its variability is a challenging task due to the sharp "climate divide" in the transitional zone between Atlantic, continental and Mediterranean influences and due to the complex orography, spanning altitudes between 0 (sea level) and 4800 m (highest mountain peaks in the western Alps).

High altitude regions are generally recognized as being particularly sensitive to climate change. For example, problems may occur due to the impact of climate change on the ecosystem. The rapid retreat of glaciers and the melting of permafrost have been observed during the last decades. Morainic material, debris and rock walls may get destabilised due to glacier down wasting and permafrost degradation. Vegetation reacts very sensitively on climate amelioration or deterioration (e.g. shift of upper tree line). Climate change is expected also to show its impact on the socio-economic systems, e.g. in summer and winter tourism.

Climate change impacts can be sub-divided in long-term trends and evolutions on the one hand and short exceptional events on the other hand. Long-term trends and evolutions include effects on glaciers, on permafrost, on long-term geomorphic processes, on the annual and long-term snow-line, on frost and frost exchange, on growing periods of plants and on the upper tree-line. Short exceptional events include effects on avalanches, on debris flows and flash floods, on dry periods and their consequences for the vegetation (including forest fires) and on wind storms and forest devastations.

To study past climate variability on regional scale an adequate data set is necessary: high quality data as long as possible and as dense as possible. Fortunately, the Alpine region offers the potential to create such a dataset. Its climate station network belongs not only to the densest of the world, its longest time series are able to display climate variability back to the 18th century. However, many of such series could not been utilised up to now. A treasure of data has been hidden in archives on paper sheets, has not been digitised and its quality did not allow for any further climate research. FORALPS WP5 took the chance to search for hidden or even unknown data, to digitise data in order to save them for deterioration, and to work on the enhancement of their quality. This required the study of metadata as well.

During the 20th century the **Austrian** network developed from the network of the Austro-Hungarian Monarchy to the recent network of the Republic of Austria with an increase of stations in the course of time, but with interruptions during the years of the First and Second World Wars. During the First World War there were only slight reductions in the network in 1914 and 1915 followed by a strong reduction in 1916. Due to economic difficulties the network recovered slowly in the early 1920s. A sharp break in the network density occurred during the years of World War II. Many observers had to serve in the German army and could not be replaced. The worst loss of Austrian climatological data occurred in 1944. The complete original historical data of all the Austrian stations were transported to the archives of the German "Reichswetterdienst" immediately after the occupation of Austria in 1938, and burned during a bombing of the city Berlin in 1944. This had serious consequences for climatology in Austria. With a few exceptions, data could only be reconstructed from 1944 onwards and then only from the printed yearbooks. All of the other data (including also a certain part of metadata) was lost or destroyed in 1944 (Auer et al., 2001). To overcome this far-reaching data deficit, Austrian Zentralanstalt für Meteorologie und Geodynamik concentrated its efforts during FORALPS Project on activities aiming to recover as many series as possible from the data archives of the Regional Hydrographical Offices.

On the very small territory of **Slovenia** three major climate systems (Sub-Mediterranean, Alpine and Continental) interact with each other. A large part of Slovenia consists of mountains or lower hills, which are influenced by the Adriatic Sea on the southwest and by the continental climate of the Pannonian basin on the east. This is the reason for very high precipitation variability. There are regions in the western part of the Julian Alps where annual precipitation exceeds 3500 mm, while in the east it hardly reaches 900 mm per year. The same high variability is well expressed in temperature conditions. Western Slovenia has a more temperate climate with smaller temperature differences and eastern Slovenia has a more severe climate with higher temperature differences (daily and seasonal). The lowest temperature occurs on high altitude Alpine plateaus in the presence of snow cover when a strong temperature inversion forms in the shallow basins. Additionally, the high variability in elevations (from 0 m up to 2864 m) makes the alpine climate system more variable and more sensitive. This spatial variety is also reflected in climate variability over time and is an important factor determining the impact of global climate change in the country.

To predict future climate as reliably as possible, we have to know the past condition as accurately as possible. Long data series of all meteorological variables are one of the most important information about the past climate. The Slovenian ecosystem is very sensitive to small changes in climate. Snow plays a major role in influencing Alpine climate, and snow has a very sharp threshold in respect to temperature; for this reason changes in climate can lead to abrupt changes in alpine climate and ecosystem. The predicted changes in temperature in the central part of Slovenian Alpine region for the next 100 years are up to 7,4 °C in summer and 6,1 °C in winter. Also the precipitation regime is supposed to change. Summer time will be dryer, while in winter time there will be more precipitation. To adapt to predicted changes in climate, climate monitoring is essential. Due to very high spatial and temporal variability of climate variables in the Alpine region, there is a need for high spatial and temporal measurement density.

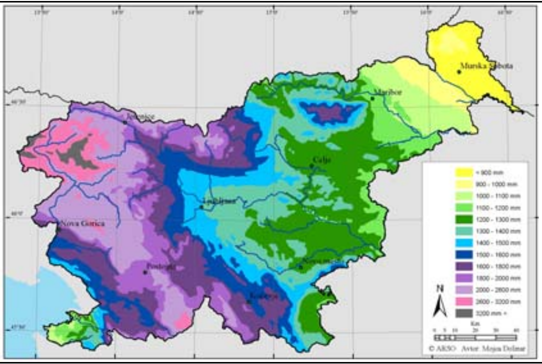


Figure 1. Mean annual precipitation in Slovenia 1971-2000

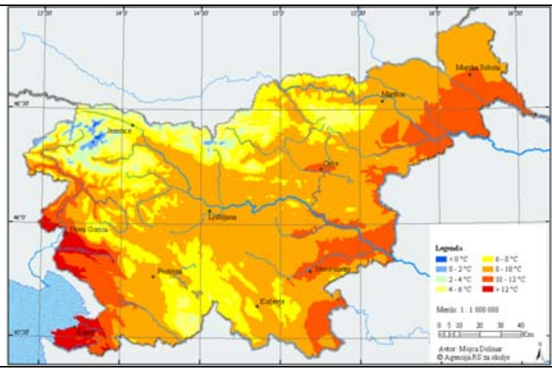


Figure 2. Mean annual temperature in Slovenia (1971-2000)

The aim of the Environmental Agency of the Republic of Slovenia, as a partner in WP5, was to improve the knowledge of the very sensitive alpine climate. To access past climate variability in the region of the Slovenian Alps, old data archive was digitised in order to construct long data sets. False signals in data sets were removed during the homogenisation process and the influence of homogenisation process was analysed in order to access the errors in trends, calculated on non-homogenised data sets. In the past most of climate trends were calculated on relatively short data series (up to 50 years) what influenced the calculated trends. This influence of data series length on the significance of trends has also been analysed

2. Partnership

The Partnership of FORALPS WP5 comprises eight partners of three countries, Austria, Italy and Slovenia. A short description of the partners who contributed to this report is given in the following.

2.1.Austria

The Weather Service of Austria, Zentralanstalt für Meteorologie und Geodynamik (ZAMG) has been responsible for the Austrian station network since its foundation in 1851. It is holding the data archives and digital climate data bank, and stays in close contact to the Hydrographic Service of Austria. Besides the headquarters in Vienna, four regional centres in Graz, Innsbruck, Klagenfurt and Salzburg have been established to manage all regional affairs in respect to weather forecast, climatology and environmental studies. The Austrian provinces Wien, Niederösterreich und Burgenland are managed by the headquarters in Vienna (ZAMG-W).

2.1.1. ZAMG-W

The department of Climatology has been responsible for the execution of FORALPS Project. The specialised branch "Klimatologische Landesaufnahme und Hydroklimatologie" has been working in close cooperation with the branch of "Daten und Stationen" to reach FORALPS WP5 project goals.

2.1.2. ZAMG-I

The Climatology Group of ZAMG-I has been working on the development of long time data series observed at stations in alpine regions in Tyrol. One of the main objectives has been to work on the digitalization of paper data for temperature and snow parameters. The group has experience in quality control and homogenisation of long-term data sets and in operating the regional station network.

2.2.Italy

Climate monitoring in Italy has a long history and has passed through many different offices. The systematic monitoring activity started for hydrologic purposes in 1912, with the creation of the National Hydrographic and Mareographic Service, which managed a huge amount of conventional stations, with mostly paper data and metadata. It recently moved to the local government and all the paper and informatics properties were given to the regional/provincial environmental agencies.

2.2.1. ARPA Lombardia

Arpa Lombardia is the Environmental Regional Agency of Lombardy, from 2003 onwards it has been managing the conventional station network of Lombardy and all the data recorded. As an initial work Arpa Lombardia had to arrange the inventory of all the paper data. It also works on the management of the hydrologic part of the automatic stations network of the Agency, the digital data validation and publication in weekly and monthly bulletins, the paper data and metadata digitisation, validation and filling, discharge measurements. There's also a continuous work of data and metadata rescue through unconventional data sources, such as letters, publications, etc.

2.2.2. PAB

The Hydrographic Office of the Autonomous Province of Bozen – South Tyrol was established in 1976. Before the end of World War I South Tyrol was part of Austria and all the measurements were executed by the Austrian authorities. After the war, South Tyrol became part of Italy and all the data were sent from Austria to Italy. These records have been lost. From 1921 until 1976 the measurements were made by the "Magistrato alle Acque - Venezia". In the database of the Hydrographic Office are daily measurements stored since 1921, but most of the data from the Austrian period were lost. Within FORALPS it has contributed to the recovery of lost data from the period before World War I.

2.2.3. UNITN

The Atmospheric Physics Group at the University of Trento, Department of Civil and Environmental Engineering, has worked in recent years at the reconstruction and climatological analysis of long time series of air temperature and precipitation measurements in the area of Trento and surroundings (Rea et al., 2003). Within FORALPS it has contributed to the analysis of various series from Fiemme Valley (in cooperation with PP PAT) and of the temperature series of Verona (1741-2006) (see Appendices)

2.3.Slovenia

At the beginning of instrumental meteorological measurements in 1850, Slovenia belonged to Austro-Hungarian Monarchy. With small exception, almost all Slovenian territory was in Austrian part of Monarchy. The north-eastern part of Slovenia, called Prekmurje, belonged to Hungarian part. Hungary was autonomous entity.
After the First World War in 1918, Slovenia was a part of Yugoslav Monarchy, with exception again. The south-western part of the country, called Primorska, belonged to Italy.
After the Second World War Slovenia was one of Republics in the Social Federative Republic of Yugoslavia, Hydro-meteorological Institute of Slovenia was a part of federal one in Belgrade.
Since June 1991 Slovenia is an independent republic. Hydro-meteorological Institute of the Republic of Slovenia was reformed in 2003 into the Environmental Agency of the Republic of Slovenia..

2.3.1. EARS

In Slovenia EARS owns the meteorological archive and national meteorological network and everything that goes along: instruments, stations, measurements and observation, data control. Data control and archives section is responsible for data collection, data quality control, validation, and archiving. It manages the national meteorological database. The Climatology Section is responsible for data homogenisation. Regular climate reports, more or less detailed climate analysis for end-users and climate research are also carried out in this section. In recent years both departments have been involved in many European projects dealing with meteorological databases, climate monitoring and climate research.

3. Climate Data

Climate data is the basis of all climatological research and application. Better data allows for better results. Therefore in FORALPS great attention was given to creating and working only with high quality data. The goal of WP5 dataset may be stated as the following: creating a climatological database to allow for regional climate change studies in the Alpine region. In particular,
1.) studies on frequencies, on the seasonality, on areal extent and spatial patterns of extreme events (temperature, precipitation, snow)
2.) further climate impact studies
3.) support for planning and decision making

Such a dataset should have an optimal spatial and temporal resolution, should be as long as possible, should only reflect the real climate variability (as homogeneous as possible) and should not contain only temperature observations. The necessary steps will be described in the following sections.

3.1.Data Recovery

There are still historical climate data and metadata waiting to be recovered, deposited in archives of monasteries, cloisters, libraries, universities, in the archives of weather Services, Hydrographical Services or maybe even at the observers' homes. FORALPS WP5 partners took some initiatives to search for such "hidden" climate data to create climate time series supplementing and extending the existing data bases.

3.1.1. ZAMG-W

During World War II Austria lost nearly all its original climate data sheets. All climate sheets had to be sent to the "Deutscher Reichswetterdienst" in Berlin where they burned completely after a bomb attack. To create –as many as possible – centennial series ZAMG-W continued its activities in data recovery, looking into printed sources – e.g. Jahrbücher der Zentralanstalt für Meteorologie and Jahrbücher des Hydrographischen Dienstes in Österreich - searching in cloisters and libraries of universities. Within FORALPS, the archives of the nine regional Hydrographical Services (Hydrographische Dienste der Bundesländer in den Ämtern der Landesregierungen) and the Austrian Hydrographical Service (HZB – Hydrographisches Zentralbüro) have been contacted in order to find respective data of precipitation, snow and temperature to reconstruct the destroyed series back in time. This attempt turned out to be rather successful, however less data were found than what was expected.

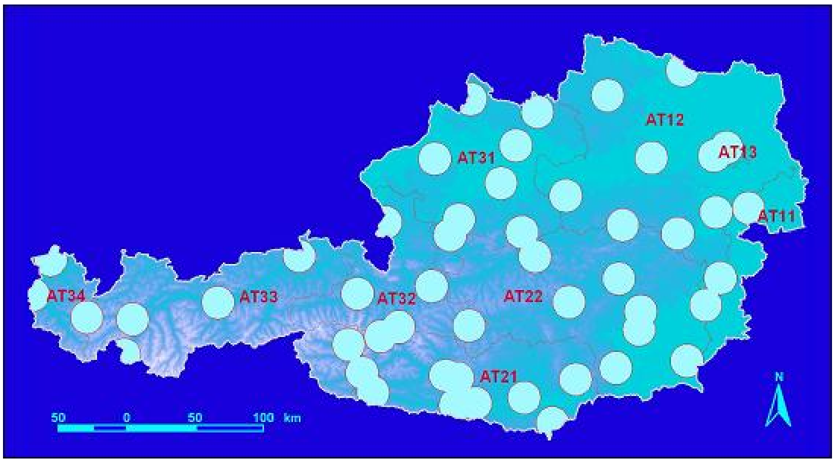


Figure 3. Target regions for data recovery attempts of ZAMG-W

The search for metadata was undertaken in parallel to the data recovery attempts. Complete metadata describe the history of a station since its establishment up to the present (Aguilar et al., 2003). As many details as possible (in respect to the history of local conditions, instruments, operating procedures, data processing and other factors pertinent to interpreting data) have been collected to contribute to the reliability of long-term series and to confirm breaks detected by homogeneity test results.

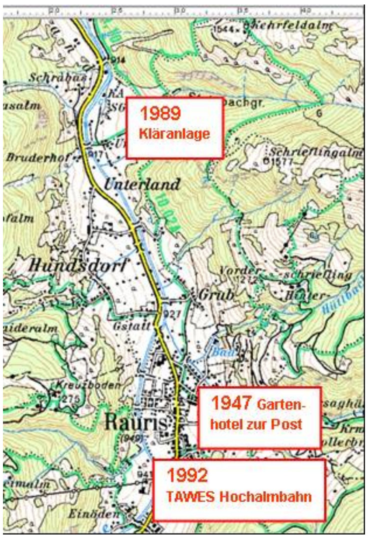


Figure 4. Three locations of the inner-alpine station Rauris during the last 60 years. Two of the five relocations could not be reconstructed. precisely

Figure 5. Historic photos of the station in Rauris with Anton Schattauer, observer from 1935 to 1946 (photo H. Tollner, 1935)

3.1.2. *ARPA Lombardia*

Historical series are extremely important for civil protection (design and planning), for water-use planning and for climatological studies. Additionally, ARPA Lombardia receives and must satisfy frequent data requests from public and private bodies on historical data contained in the archives. These considerations immediately highlighted the necessity of a careful organization of all the data inherited from the previous owners. Without any order the archive would remain incoherent and absolutely useless. In this situation the benefit of having a paper data archive inventory is the knowledge of the existence of a data series before its digitisation, allowing for a better management of the digitisation process. It's a typical problem of an office with a huge amount of paper data, where it's worth choosing what to digitise and when.

To avoid future damages of the documents, it was essential to protect them in suitable boxes, to find suitable software to collect all the archive's inventory and to specify a methodology suited to the necessity of the office (i.e., to be informed about the existence of particular documents with great accuracy and detail).

Firstly an approximate distinction has been carried out, subdividing long term series of rainfall, temperature and water level data, and subdividing records by type of gauges (mechanical or manual).

Subsequently, each data series was saved in file cards and each year was fully controlled in order to identify any missing data support (weekly strip charts or monthly boards). Moreover, the reconstruction of a long term series implied a check of some metadata (catchment, station's name, notes of the observers, gauge type, changes in the past). In this way not only a simple list of stations in operation throughout the ages was created, but also a first archive of metadata was conceived, with the possibility of querying the database.

At the end of this work, which lasted 6 months, the organized documents needed a new placing. It was decided that the most recent documents and all the dossiers related to the uptakes have to be in the wardrobes of the new rooms of the office (Via Confalonieri, 29), the yearbooks were to be kept inside the reading room to be consulted, while the maps, the bibliographic materials and the long technical series had to be on the bookcases in the basement. Also a part of the shelves and of the bookcases was left empty to store the future data and paper documents.

Figure 6. Final situation (the archive on the left, the Yearbooks in the reading room on the right)

Sesamo enables to identify the exact location of a searched document by retrieving the classification, the number of the box, the number of the bookcase and the number of the shelf. Each box is identified by a label with all the important information: ARPA Lombardia logo, classification, box number and what is stored inside (station's name, catchment, data type and the years included). Additional information is given in *Appendix 1: Arpa Lombardia Archive: the past and the present*

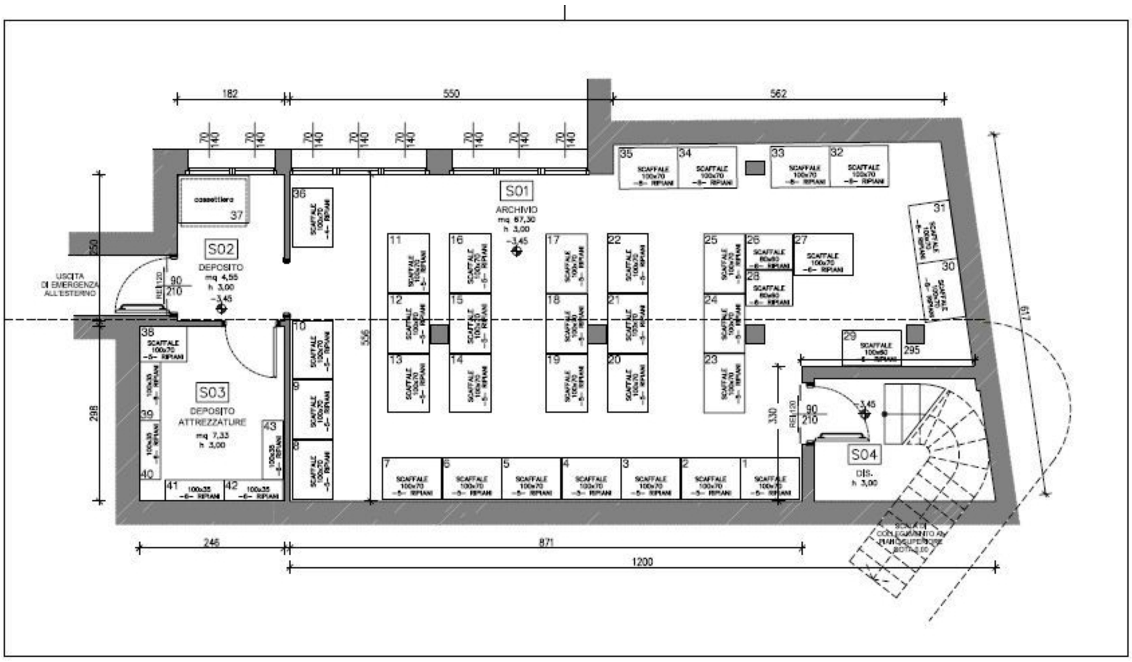


Figure 7. Map of the archive room.

3.1.3. PAB

The main target during this project was the recovery of lost daily data from the period before World War I. To recover this data, PAB contacted many cloisters, archives and private persons. PAB concentrated its research on four stations: Bozen - Bolzano, Brixen – Bressanone, Marienberg – Monte Maria and Toblach – Dobbiaco.

First PAB tried to find as many metadata as possible. Particularly the station in Bozen exhibits several permanent changes of location. It was not possible to reconstruct the precise dates of the relocations, however the exact locations of the station could be determined (Fig. 8), and also references to the instruments were found (Fig. 9).

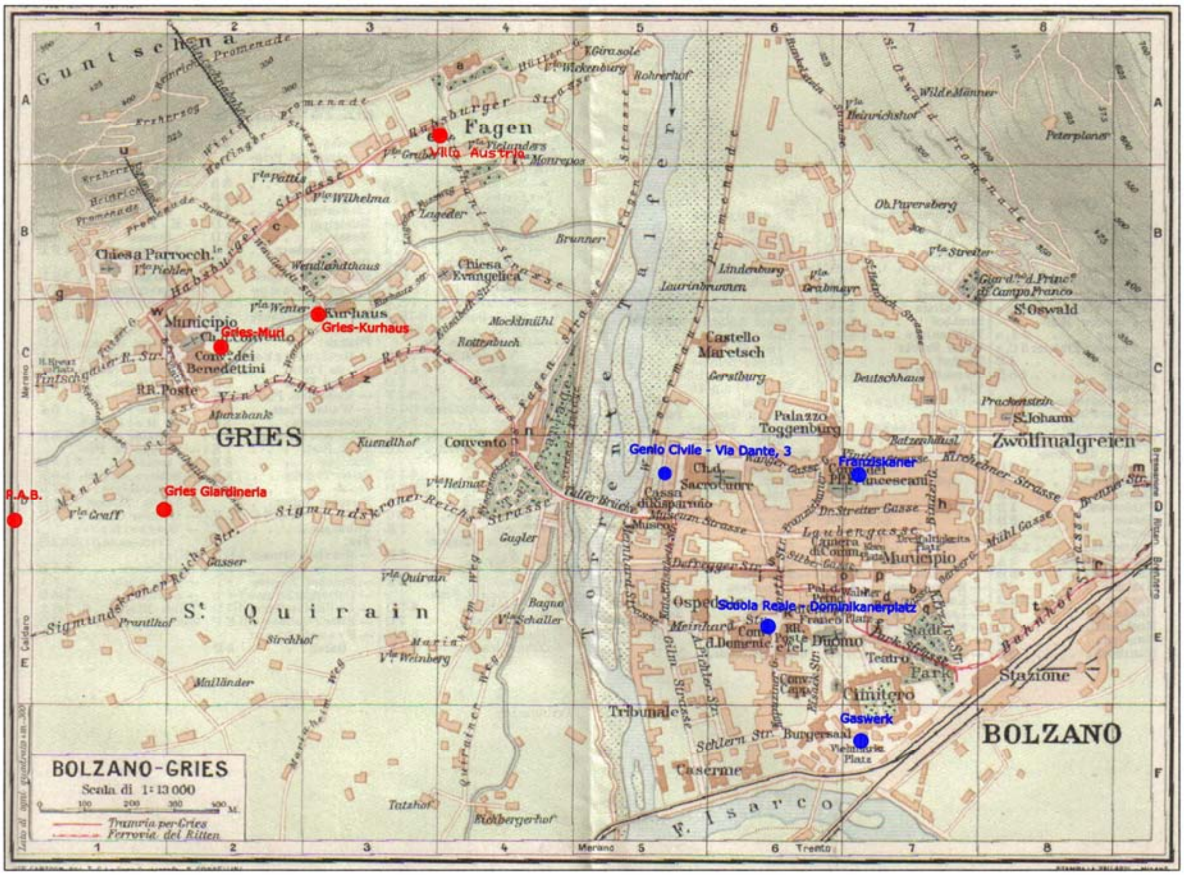


Figure 8. Locations of the station Bozen – Bolzano Gries (red dots)

Figure 9. Old meteorological station Bozen – Bolzano at the roof of the “Kurhaus Gries”, 1929

Precipitation and temperature data were found in the “Jahrbücher” from the Hydrographic Service Austria (1893 - 1913).

Additional data from Brixen – Bressanone could be recovered in the seminary “Vinzentinum” (daily observations of temperature, air pressure, humidity, cloud cover, wind, precipitation and thunderstorms from 1910 until 1921). They do not have any gaps during World War I (Fig. 10).

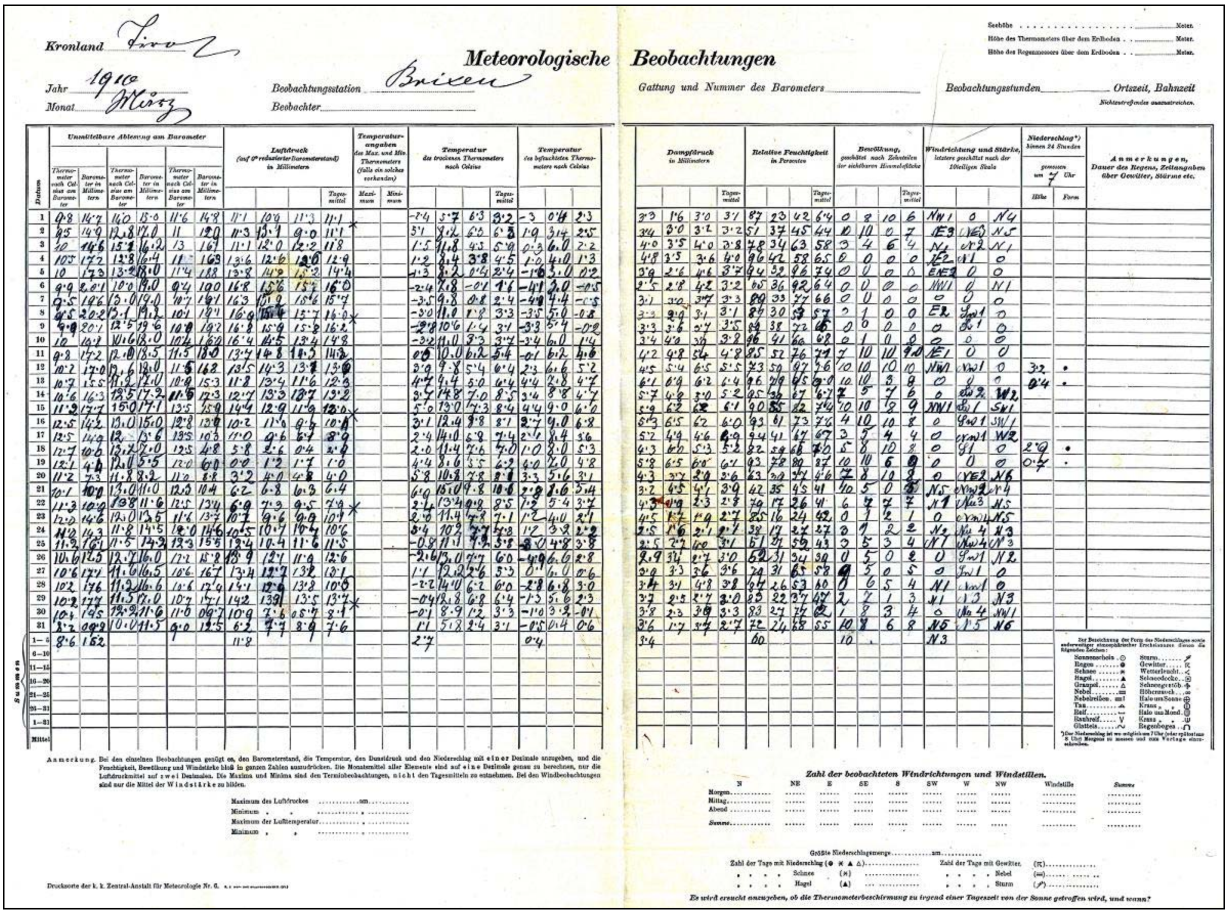


Figure 10. Data from Vinzentinum Brixen, March 1910

Although PAB searched in different archives of Italy no new data could be recovered, in particular the original data from the time of the monarchy was not found.

3.1.4. EARS

EARS has inherited a large archive of measured meteorological data. Some of them were measured even in 19th Century. In the beginning of the observation period, Slovenia was part of the Austro-Hungarian Monarchy. Not all logbooks from that time are preserved. Some of them were destroyed or lost forever. In spite of destruction of original logbooks, some data could be recovered from other sources such as newspapers, yearly publications, etc. EARS studied Austro-Hungarian "Jahrbücher" and newspaper "Laibacher Zeitung" in which data of two years of daily observations for Ljubljana has been retrieved (three observations per day). Some of the Jahrbücher are in possession of EARS, while some of them were discovered in the library of the University of Ljubljana. As it was not possible to copy these volumes, the digitising was made by photographing the books. The digitisation of books was paused due to renovation of library.

Figure 11. Precipitation data are stored in boxes and arranged by stations. Last years, data are arranged by date of observation.

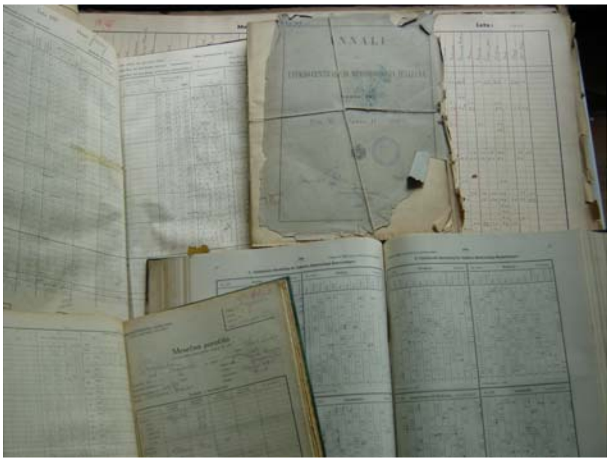


Figure 12. Meteorological logbooks from different times in past when Slovenia was a part of other countries.

Metadata

Along with meteorological data EARS also keeps a metadata archive. In the past metadata has not been always considered as important for meteorological or climatological work. Therefore EARS has lost a lot of metadata, as changes have not been documented at all or as the documentation has not been updated. Because of its importance there is now a need to reconstruct it.

The reconstruction of historical metadata is hard work. First we check out all documentation of the meteorological station and observing site (sketches, photos, descriptions of sites), meteorological logbooks, old records of meteorological stations (Jahrbücher, Annali Idrologici, M. Povše: Seznam krajev z vremenskimi postajami v SR Sloveniji in s kronološkim pregledom meteoroloških opazovanj do leta 1984), old articles and literature (A. Gavazzi: O meteoroloških postajah v Sloveniji and J. Pučnik: Velika knjiga o vremenu, M. Trontelj: 150 let meteorologije na Slovenskem). For specialised information other institutions have to be contacted (e.g., National and University Library, Geographical museum at Anton Melik Geographical institute, Department of Geography at Faculty of Arts -University of Ljubljana). Even the meteorological observers are sometimes source of information.

For the reconstruction of locations of meteorological sites we need at least addresses of observers, because geographical coordinates from that time are not precise enough. Sometimes we can infer the location of meteorological station from observer's profession (priest, school master), because they were living in the school or in the building next to the church. Churches are still today on the same place with the exception of south region called Kočevska, where almost all churches have been ruined.
Old sketches of meteorological stations are a good source of information. In the time of Austro-Hungarian Monarchy and in Yugoslav Monarchy sketches were very precise,

and kept up to date. Later, after Second Word War in Yugoslavia, the sketches are smaller and usually not updated (often there is no date at all on the sketch).

Using the collected information we reconstruct the location of a meteorological station. This location it is placed on a map, ortho-photo or plan; then location's pictures and text descriptions can be taken on-site. This reconstruction cannot always be taken for granted; the surroundings of the site have often been changing (Figure 13) and sometimes they could not be reconstructed from the text description.

Figure 13. Location of meteorological station in Nova vas from 1965 on the left, and from 2007 on the right.

The main problems in reconstruction of historical metadata are:

- Insufficient documentation for different locations of one meteorological station, non-standard observation time, non-standard measurement units (Paris lines for precipitation), changes in station's surroundings (city growth, etc.),
- Several archives of meteorological data in Slovenian history:
    - Archives of Austro-Hungarian Monarchy; Austrian part of the Monarchy had good metadata; on the other hand Hungarian metadata is unknown. North-eastern part of Slovenia was in the Hungarian part of Monarchy and meteorological data and metadata are missing, supposedly they were given to central archive of former Yugoslavia in Belgrade.
    - Italian archive, south-western part of Slovenia belonged to Italy in the period of 1918–1941. Most of the daily meteorological data and metadata from Slovenian meteorological stations are still in Italy. Yugoslav archive before Second World War, metadata is quite good.

Figure 14. Meteorological stations in Slovenia in 1925. In the period 1918–1941 south-western and western part of Slovenia belonged to Italy.

3.2.Data Rescue

Data rescue has been described as the ongoing process of 1.) preserving all data at risk of being lost due to deterioration of the medium and 2.) digitising current and past data into computer compatible form for easy access (WMO, 2004). The same paper describes the critical need of the inclusion of data before the 1940's.

3.2.1. ZAMG-W

To contribute to an effective data rescue ZAMG-W has been using electronic imaging of existing climate data sheets and digitising additional data found in the archives of the regional Hydrographical Services.

Figure 15. Digitising of historic climate data at ZAMG-W, Fachabteilung für Daten und Stationen (photo: O. Chitta, 2006).

To reach the final goal of calculating climate change indices it was essential to create and provide complete time series of the 20th century (1901-2007). In cooperation with the National Hydrographical Service (NHS) of Austria we digitised more than 4 Mio daily precipitation, temperature, snow and fresh snow data. It took over one year to digitise these data values out of historical reports into excel files. Mainly students and some project collaborators worked on this comprehensive digitisation initiative.

Description of the FORALPS data inventory

Temperature

Both at ZAMG and at the Hydrographical Service historical stations temperature has been measured three times per day (t7, t14 and t21), thus digitalisation of temperature was more extensive than for other elements like precipitation (1 measurement per day). We approximately digitalised 2 millions of daily temperature data.
Fig. 16 gives an overview of the digitalised, respectively in archives and database stored daily temperature data of 77 stations. The missing values (in Fig.16- shown in red) often occurred at the beginning of the measurements and during the world war years. Of note is the late beginning of the measurements at ZAMG stations because climate sheets had to be transferred to Berlin during the World War II where they burned later. There are only sparse records before 1936 (exceptional stations: Wien, Kremsmünster, Sonnblick, Salzburg, Graz and Innsbruck).
Data digitalised by the Austrian Hydrographical Service are shown in light blue. After 1998 temperature data from the NHS was made available in digital form. The information about completeness of every single year is given by the number of digitalised months, noted as well in Fig.16. Especially around the time of the 2nd World War most of the data still show greater gaps, those periods are noted in orange). Pink cells indicate data exported from the ZAMG-KLIMA database.

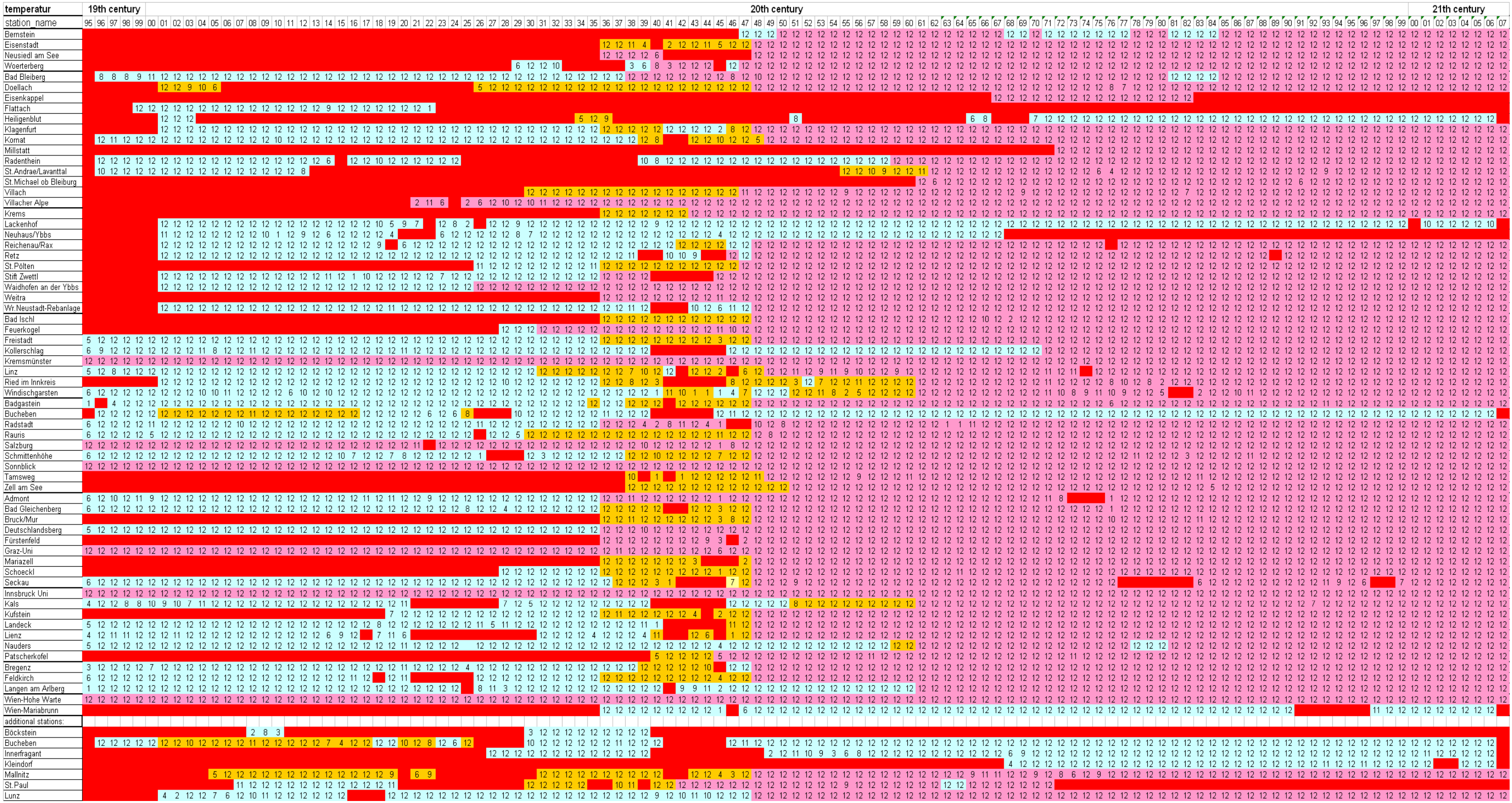


Figure 16. General overview of the element temperature

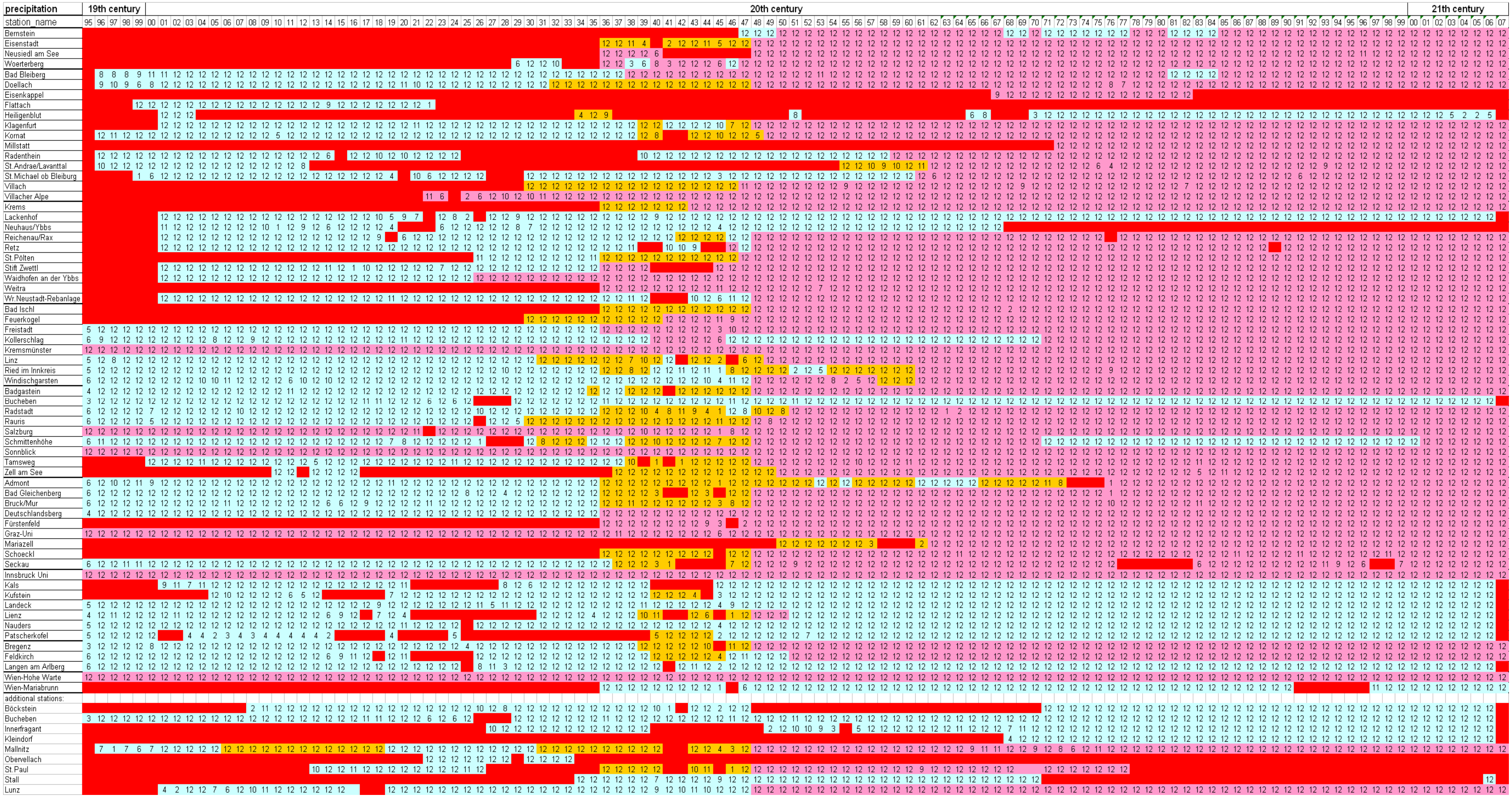


Figure 17. General overview of the element precipitation

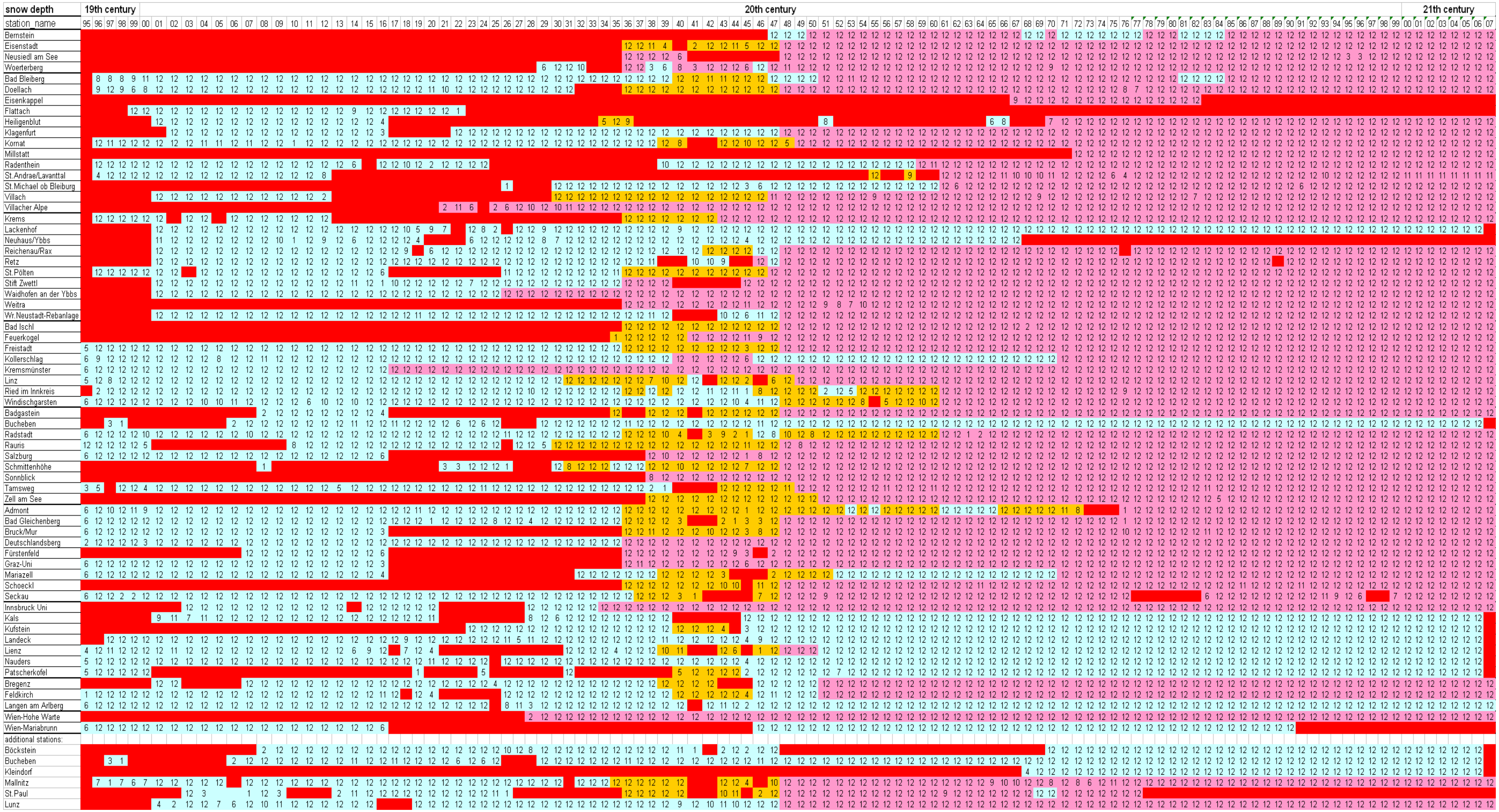


Figure 18. General overview of the element snow depth

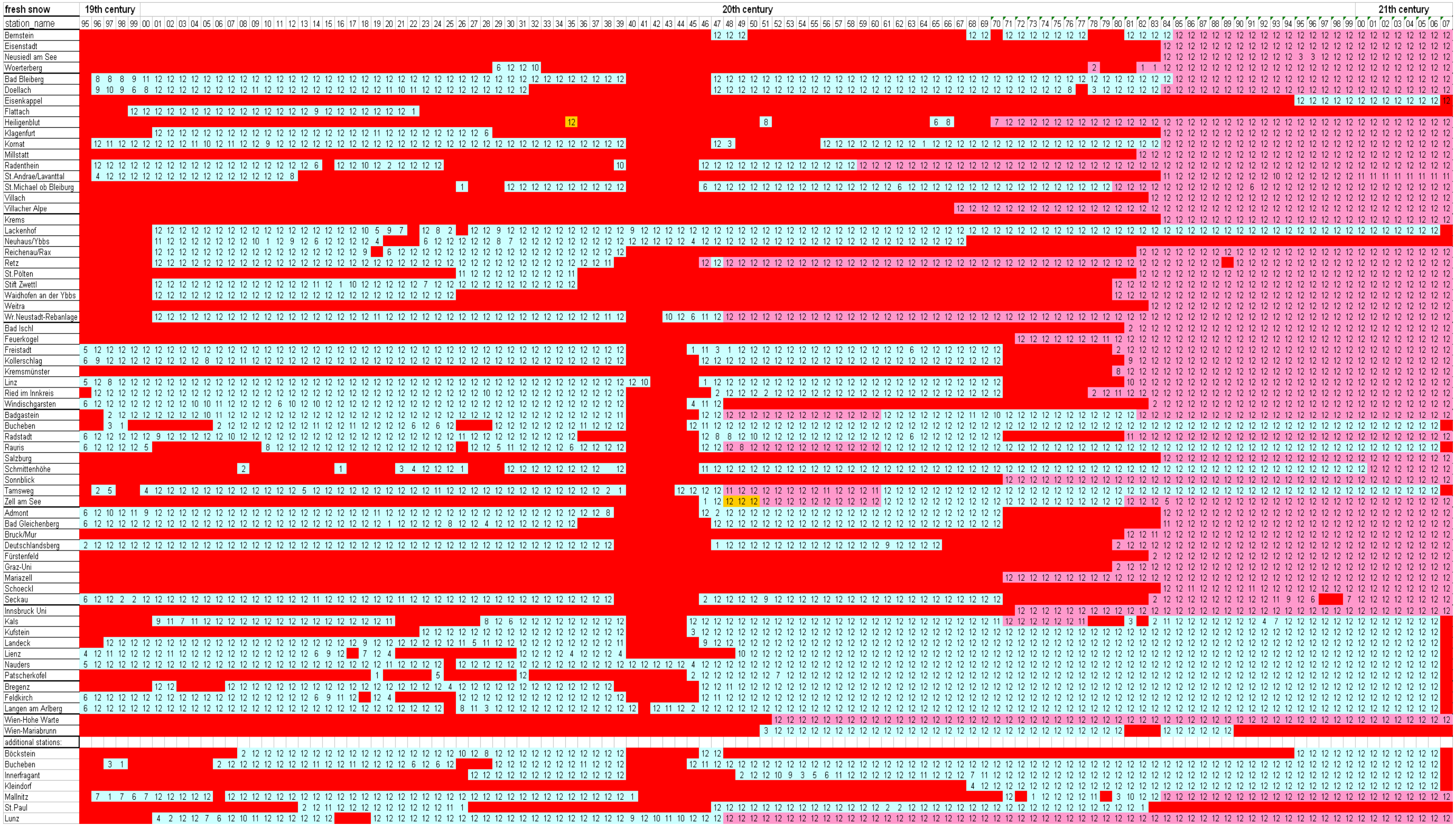


Figure 19. General overview of the element fresh snow

Precipitation

Fig. 17 shows the data inventory of the element precipitation. 46 out of 77 stations (60%) feature daily long term precipitation time series. We digitalised over 600 000 data values.

Snow depth

For the National Hydrographic Service it was always of great importance to measure daily fresh snow which strongly affects water balance. NHS started its measurements in 1895, earlier than the Meteorological Service in Austria. ZAMG collected its first observations in the late twenties (see Fig.18).
We created 14 continuous time series of snow depth and digitalised a total of 1948 station years. Results of the first statistical evaluations of characteristic snow parameters and of a first trend analysis are described in Appendix 2 (Jurkovic et al.).

Fresh snow

For Avalanche Warning Services the knowledge of fresh snow sums is of special interest. Once again the NHS recognised the importance of this element earlier than ZAMG and has been measuring daily fresh snow amount since 1895. An outstanding fact is the lack of observations from 1940-1945 (see Fig.19). In this period "*Deutscher Reichswetterdienst*" took over the Austrian Meteorological Service and the Austrian Hydrological Service respectively, and forewent measuring fresh snow. Only 4 stations measured continuously daily fresh snow amount during the Second World War (Lackenhof, Neuhaus a.d.Ybbs, Nauders and Lunz). Fresh snow measurements at the ZAMG started very late, in the mid eighties. We digitalised approximately 2600 station years.

3.2.2. ARPA Lombardia

A special report has been prepared to describe the digitization process at ARPA Lombardia (Appendix 3: From Paper to File: Digitization in ARPA LOMBARDIA by Manenti et al.).

3.2.3. PAB

The recovered data were digitized and stored in the database of PAB.
The time series of the stations have been completed (Fig. 20) and a first rough quality control has been applied. The new time series have to be homogenized and a more precise quality control must be applied. Further, data of the hydrologic yearbooks has also been digitized and stored into the data base.

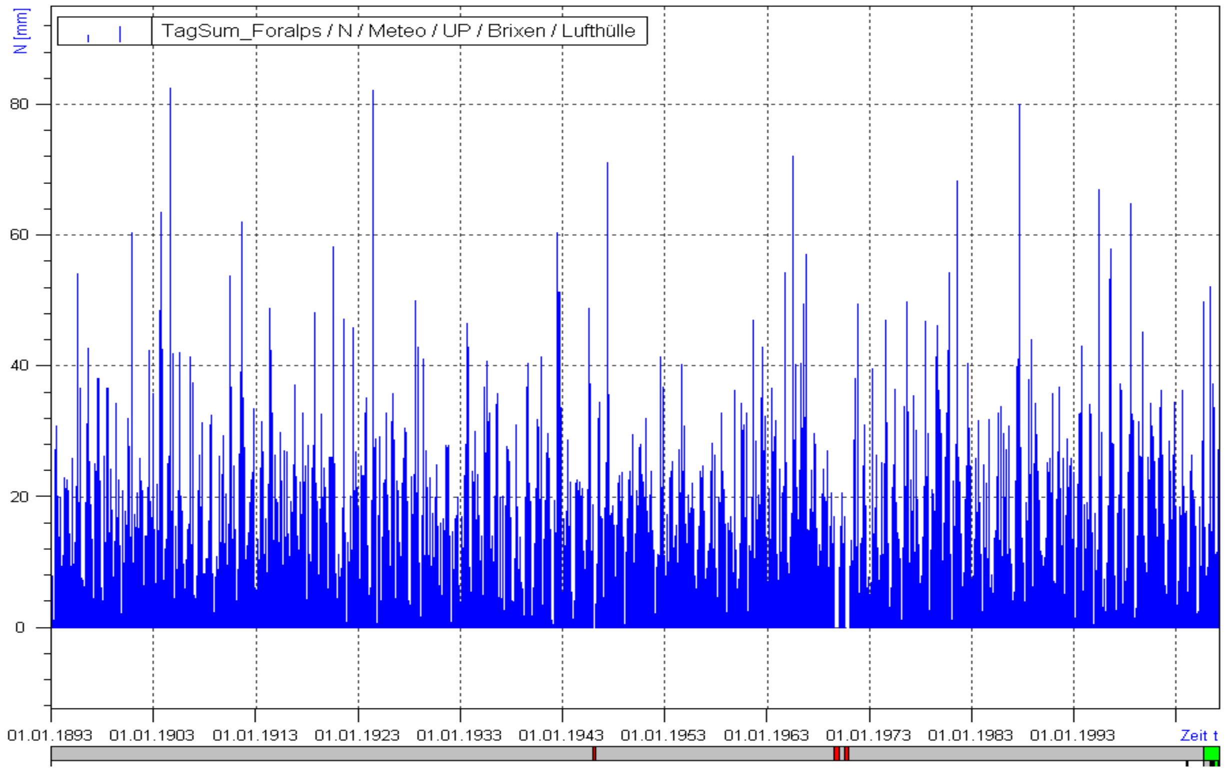


Figure 20. Daily precipitation data Brixen - Bressanone starting in 1893

3.2.4. EARS

The EARS' archive holds meteorological data from 1850 onwards. All data from 1961 have been systematically digitised, for the earlier period additionally data from a few stations only.

At the beginning of the digitisation process, a graphical evidence of EARS' digitised archive as well as paper archives was created. It shows what kind of meteorological data are available for each meteorological station, period of observation and state of digitisation. Data series with only precipitation data are marked with a different colour than series with many meteorological parameters. Incomplete data years are also marked with different colours and number of days with complete data. Non-digitised data are marked regarding to the current place of storage (different colour for different country).

Figure 21. A section of graphical evidence of meteorological stations.

EARS' archive contains about 24.000 years of data. Before the start of FORALPS project only 15.900 years were available in digital format, during FORALPS 1.360 years of data were added. So there are approximately 6.500 years of data still waiting to be digitised. Almost all digitised series contain information about precipitation, while only about 5.500 years of data include temperature measurements and other meteorological data.

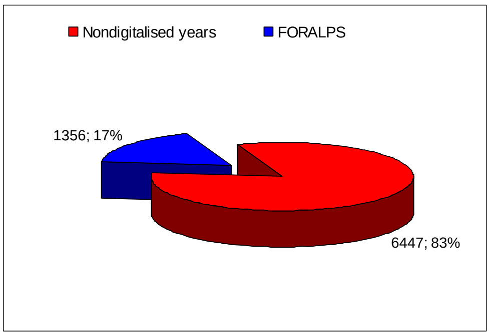


Figure 22. Percentage of digitised data during the FORALPS project according to non-digitised data

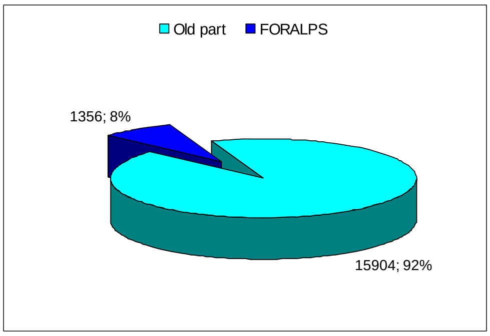


Figure 23. Percentage of digitised data during the FORALPS project according to digitised data

EARS has developed a special application for digitising data from manual meteorological stations when the appearance is similar to the actual form of logbooks. Problems occurred when digitising historical data, when the logbooks have a different form and mismatch could easily happen. The application includes all possible logical controls and range limits. Again, some historical data is problematic, e.g. when temperature was measured with Six's thermometer, which has a scale with a 20 °C offset. Temperature measured with this scale can exceed range limits and cannot be directly entered and later recalculated, which can also lead to errors in data.

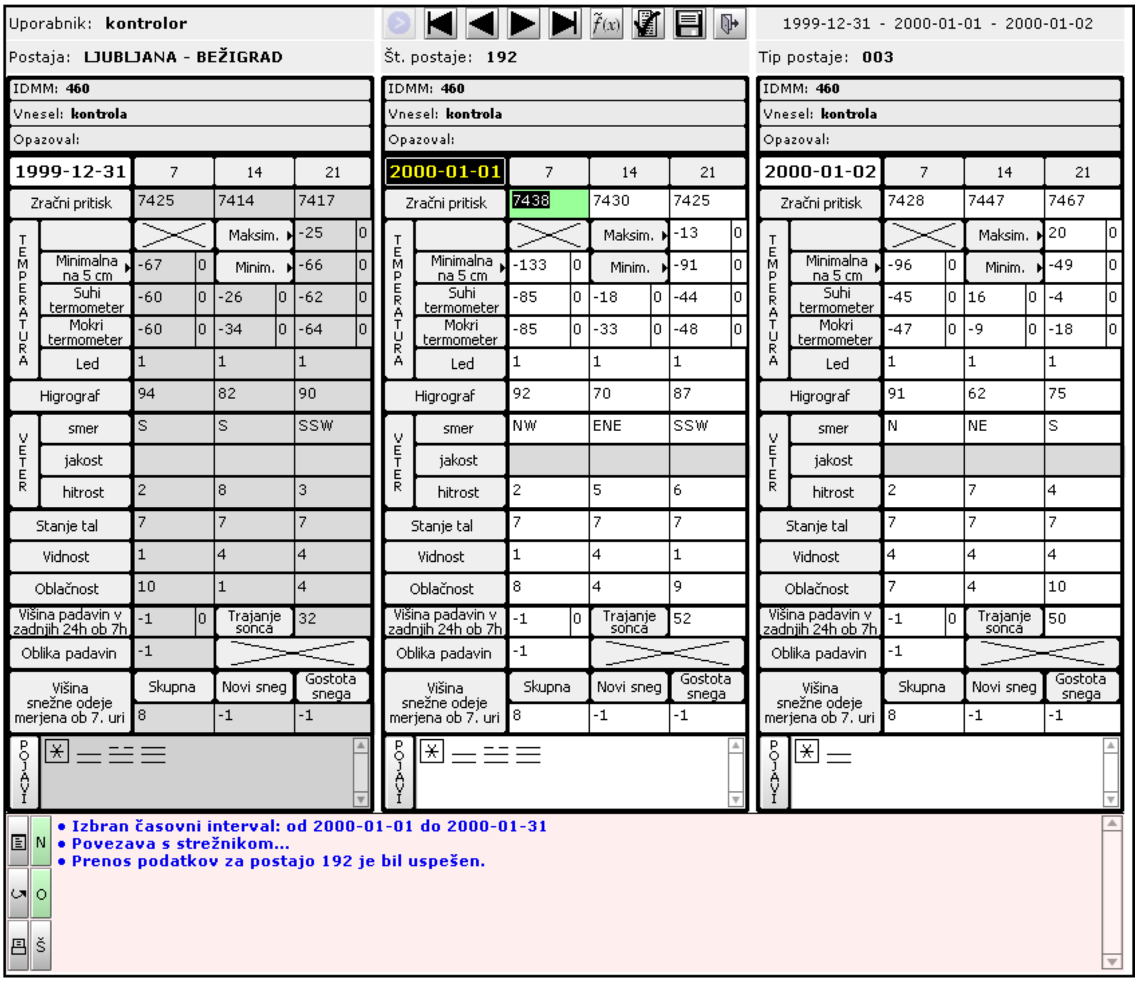


Figure 24. Application for digitising data from climatological stations.

Metadata

Before FORALPS project, the archive of metadata in EARS was mainly a paper archive. The digital one has been forming more recently. The latter one contains the same data as the paper archive of metadata. Metadata is still managed using both paper and digital archives. The digital archive of metadata was extended by:

- 105 sketches of meteorological stations from period 1890–1918,
- 351 sketches of meteorological stations from period 1918–1941,
- 344 sketches of meteorological stations from time after 1945 and
- 157 old photographs.

Metadata of 70 meteorological stations was reconstructed.

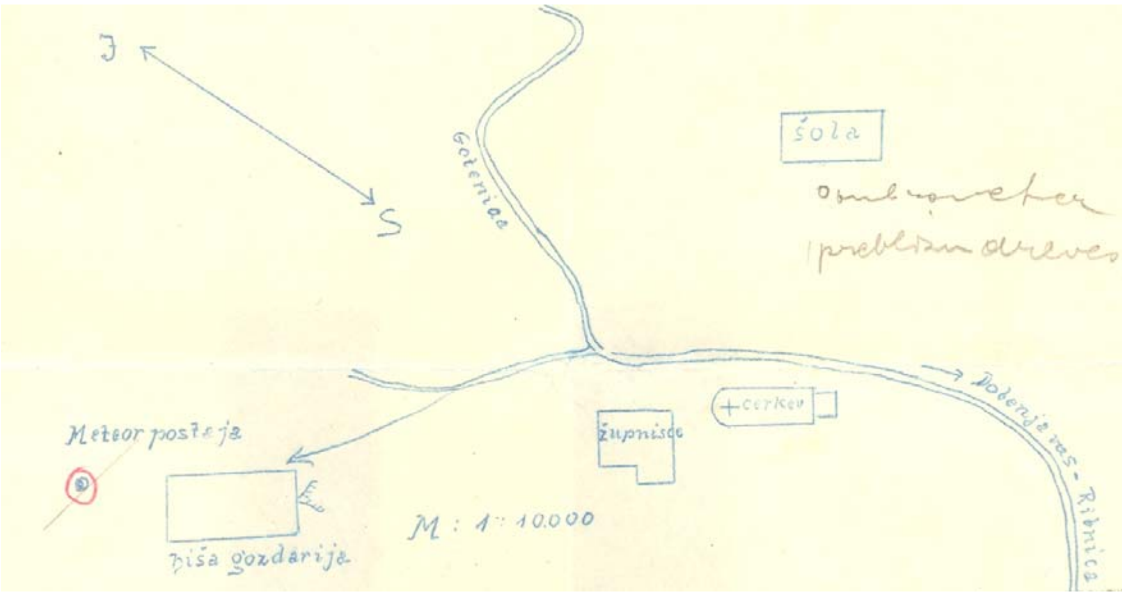


Figure 25. Sketch of the meteorological station in Grčarice from 1925. Location of instrument is marked. The church was ruined in 1949; reconstruction of metadata is therefore difficult.

3.3. Tools for Data Quality Assurance

The detection of errors in climate data demands for carefulness and use of best methods. Abbott PF, 1986 has described a number of useful methods to be applied on climate data, for FORALPS additional methods have been in use. In FORALPS WP5 this especially concerns the homogeneity tests on the long-term series and the inclusion of metadata in the homogeneity considerations.

3.3.1. ZAMG-W

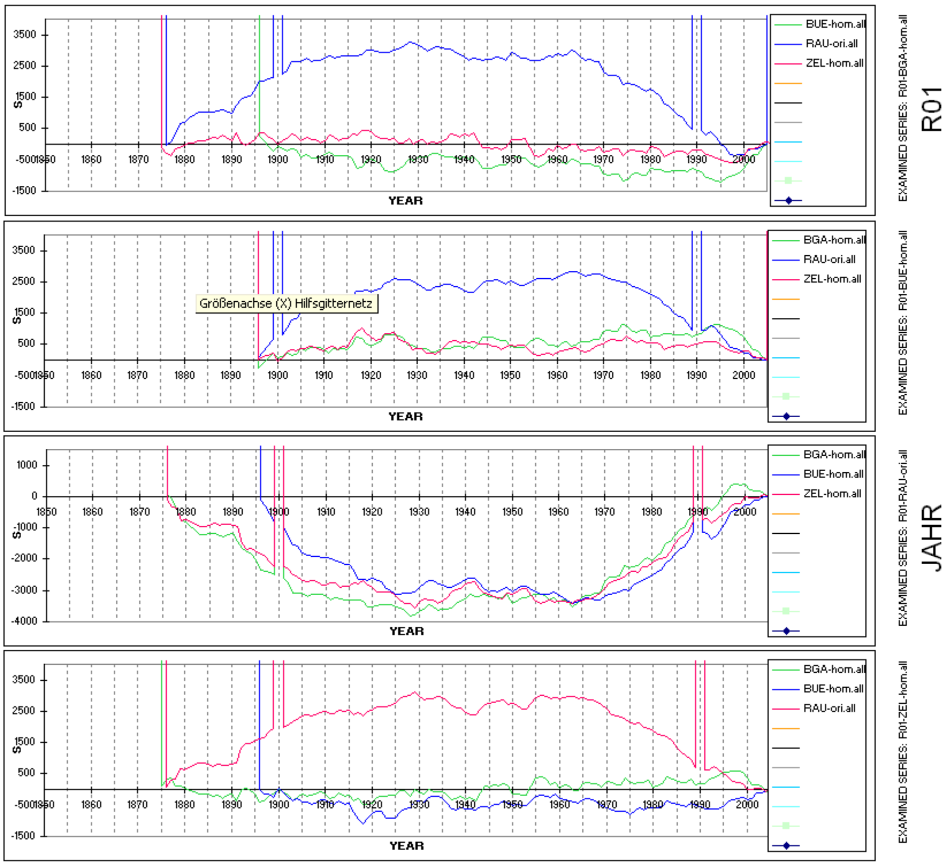
Quality Control

All newly digitised daily temperature and precipitation data have been quality controlled together with existing digital data for the recent period. These quality control procedures detected differences in the observing practices between ZAMG and the Hydrographical Service in respect to the temporal assignment of a precipitation day and the calendar day. This resulted in an intermittent unsystematically distributed shift of 1 day. For the spatial quality check the GEKIS procedure developed at ZAMG has been in use (Potzmann, 1999). A special treatment has been applied for daily snow data described in Appendix 2: Generation of a daily snow depth dataset for Austria and some surrounding regions by Jurkovic et al. This report includes information on the digitalisation process as well (q.v.).

Homogenisation

To assure the quality of long-term series ZAMG-W utilised the HOCLIS procedure (described in Auer et al., 2001 and improved in Auer et al., 2005) for monthly values and in a modified way for the daily data as well. The monthly adjustment factors for temperature have been applied to the daily values with a further 30 days smoothing to avoid breaks at the beginning and end of the respective months. In the case of precipitation this method could only be used if it has been assured that the frequency of precipitation days was not biased by inhomogeneities. For precipitation then no smoothing has been applied. This procedure is similar to methods described by Vincent et al., 2002 or Brunetti et al., 2004.

HOCLIS does not trust the existence of one homogeneous reference series a priori, but it always takes a couple of series into account. No series is expected to be homogeneous on from the beginning, but each series is supposed to be inhomogeneous. Testing is done in groups of highest correlated series, adjusting in identified homogeneous sub-intervals of one reference station.



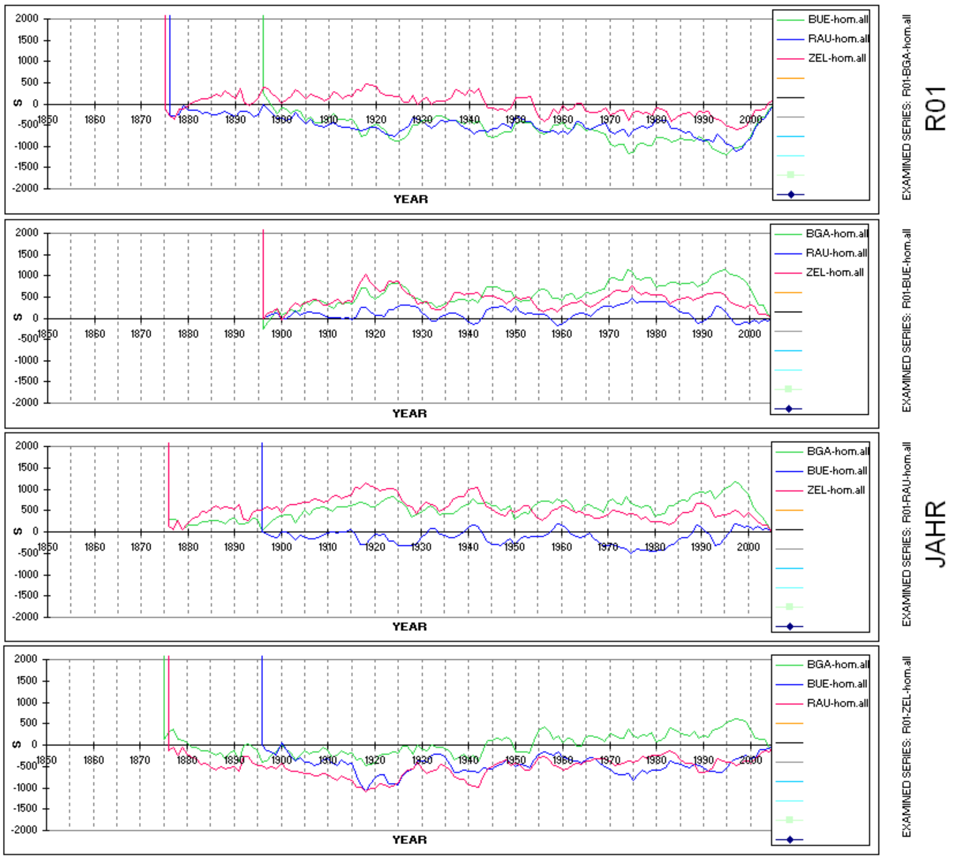


Figure 26. HOCLIS homogeneity procedure. Upper graph: station couple of Rauris, Bucheben, Zell am See und Badgastein before homogenisation; lower graph: after homogenisation.

Only few series contain complete observations. Gaps are due to many reasons: e.g. the necessary closing of one station and the time interval to find another appropriate location and observer, observers may be ill or on vacation, instruments not functioning regularly, and many others. In Austria two typical gaps related to the two World Wars affected the completeness of the FORALPS series. Using HOCLIS software tools gaps could be closed on monthly basis by applying differences or quotients of a highly correlated reference series. For daily data with reduced spatial correlation filling of data gaps requires more sophisticated tools and a higher station density. Auer et al., 2004 showed that the average spatial de-correlation distances with a common variance less than 0.5 decreases from 105 km for monthly precipitation to 42 km for daily precipitation. This means that in general daily data completion requires a high density network. For daily maximum temperature the correlation turned out to be somewhat higher than for the minimum, in all seasons except winter.

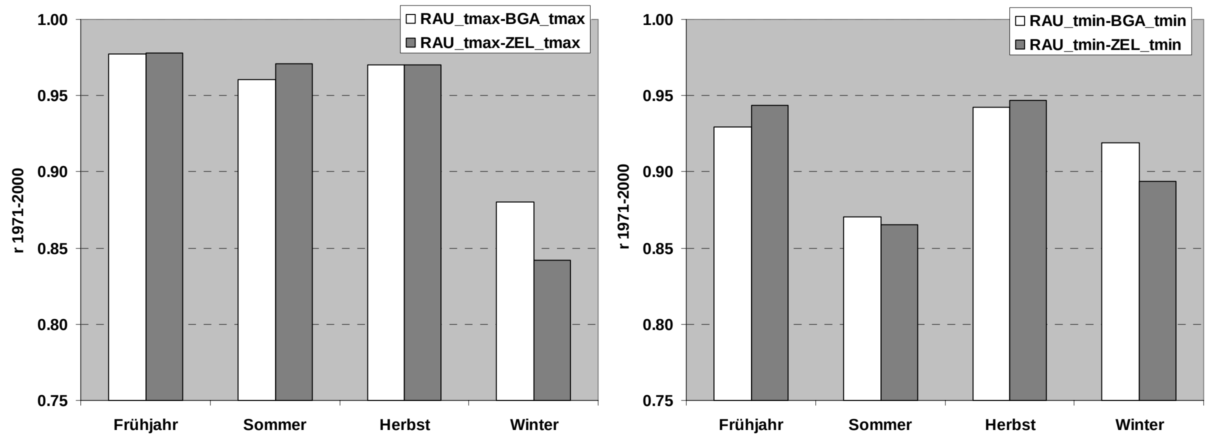


Figure 27. Seasonal correlation of daily extreme temperature of Rauris with Badgastein and with Zell am See (left: daily temperature maximum; right: daily temperature minimum).

<u>Homogenisation of an extended Austrian climate data set in order to provide homogenised climate normals of temperature for the recent period 1971-2000.</u>

Due to the current rapid climate change an urgent demand for more recent climate normals has been recognised. Although defined by WMO, the period 1961-1990 is not appropriate any more for a number of purposes. In particular, for comparisons of recent months with its normal climate a great majority of events had to be classified as "too warm", although in today's climate everybody would classify these month as cold. Therefore it was decided to prepare additional homogenised series of temperature and precipitation. By doing so, in 46 precipitation series (2648 station years) a total of 94 breaks could be detected, which means a break on every 28th year on average. Comparing temperature only 38 breaks had to be adjusted which means a break only on every 60th year in 40 temperature series. A special report on this activity has been prepared by Orlik et al. 2007 and included as Appendix to this report (Appendix 4: Homogenisation of new Austrian Time Series to Prepare a High Quality Climate Normal Dataset for the period 1971-2000).

3.3.2. EARS

<u>Data quality and validation</u>

Controlling quality of current data is a minor problem compared to quality of historical data. Data from all operating meteorological stations are digitised collectively, so there is usually enough data for spatial quality control. For precipitation control also radar-measured rainfall data can be useful. And it is still possible to call an observer and clarify suspicious values. Problems occur when controlling historical data, because usually there is not enough digitised data from neighbouring stations available and

spatial control cannot be used. There are no radar images or additional material to verify the suspicious values.
A new procedure for temperature, precipitation and solar irradiation quality control has been developed. Temperature data is first checked with logical controls and range test within digitisation. Then the observation is checked with interpolated values using data from 10 neighbouring stations from all directions around the interpolated spot (if data are available).
Precipitation data is checked with interpolated values using data from 10 neighbouring stations, automatic rain gauge data at the same station (if available) and radar-measured rainfall data. Spatial interpolation is done twice for data quality control. The first interpolated value is obtained using data from all neighbouring stations, and the second excluding up to two outliers. An inverse-square-distance method is used, normalised for monthly precipitation normals at the selected and at the neighbouring stations. The software also returns a proposed interpolation value for missing or wrong observations on the basis of most common errors (missing digit, decimal point at wrong place etc.), so the manual correction of the data is slightly simplified.

Half-hour averages of global, diffuse and UVB irradiance are automatically validated by an application written in Perl and running on Linux server. The procedure consists of various tests, based mostly on extraterrestrial solar irradiance calculated for each half hour interval. Before the quality control, correction of diffuse irradiance data for shade ring is done. All data are corrected for a systematic bias equal to the average nocturnal value (that should be zero). Global and diffuse irradiance data are validated by extraterrestrial irradiance and inter-compared. UVB irradiance data are checked with global and extraterrestrial irradiance. Interpolation of missing and false data is done in time or space or by sunshine recorder data according to Ångstrom-Prescott formula. All values get flagged using 16-bit flag system.

Homogenisation

On the territory of present-day Slovenia, meteorological observations have been performed for about 160 years. In such a long period it is practically impossible to assure the same observing site, mostly because of weather observers' replacements. In the beginning observations were mostly performed at cloisters and schoolhouses where observers were friars and teachers, so there were no reasons to change the observing site. Later on, an observation network conforming to a world meteorological standard was established and many new observing sites were added. New weather observers were employed and observing sites were usually placed near their home. Problems occurred when one observer stopped to observe and the new observer took his place. The observing site had to move near to new observers' home.

Nowadays, new problems with observers occur. It is very hard to find new volunteers who are willing to take the responsibility of daily observations for a relatively small payment, and when an observer dies the weather station usually "dies" with him. So the number of observing sites is rapidly falling and the observation network has to be reorganised. Some classical weather stations are moved and some are replaced with automatic weather stations. The automation leads to a new problem, because AWS need electric power and telephone line which are not available everywhere, so many observing sites have to be relocated again.

Every time an observing site has to move, there is an attempt to find a nearest new location or at least observing place with similar climate, but microclimate is often different. Moreover, microclimate is often changing because the surroundings of the site have been changing, especially in urban environment (new buildings, roads, etc.).

In 160 years of weather observations, methods of observation and measurements have been changing, and more so in the early years of this period. In the beginning it often happened that thermometers were installed on window shelves, balconies, terraces or even trees and not properly sheltered from direct sunlight. As a consequence exposure of thermometers to solar radiation was different from place to place. Later on, conforming to the world meteorological standard, instruments have been placed in instrument shelters (Stevenson's screens), and located 2 meters above ground, exposed to the sun. The observations are in such way representative for wider surroundings. Typical ground in Slovenia is overgrown with grass.

During the history of observation types of instruments and observing times have been changing. All these changes of the observing site and its surroundings have caused artificial signals in data sets, which should be removed before any serious climate analyses.

Three data series were subject of homogenisation: Celje, Ljubljana and Rateče. Standard Normal Homogeneity Test (SNHT – implemented in application AnClim, Stepanek) and Craddock test (implemented in application by Michele Brunetti, ISAC – CNR, Bologna) were used and results were compared. Data series from Rateče was extended by two series from neighbouring stations and homogenised. It was also compared with a data series which was entirely interpolated by the newly created routine. This routine searches for similar weather situations as recorded on the interpolation date using different parameters.

Ljubljana data series has been homogenised using both tests mentioned before. Two significant breaks have been found in 1919 and 1930 and confirmed with metadata. Reconstruction of metadata for all chosen meteorological stations is as accurate as possible with available historical resources. Metadata is managed in paper as well as in a digital archive. Both breaks were caused by a relocation of the observing site. It is interesting that the observing site did not move very far. As a matter of fact, macro location did not change, only micro location has. From January in 1919 till 1924, thermometers were placed above the window of a room with central heating. After this time, thermometers were put on a window shelf at eastern part of the building. It is not quite sure if thermometers were there till 1930 or they were changing locations in the meantime, but it is sure that measured temperatures were too high, so locations had the same microclimate. From 1930 on, measured temperature is representative for Ljubljana region and no more breaks were found. The period from 1850 till 1895 still has to be investigated in detail, but more neighbouring stations have to be digitised first to have more reference series.

Both homogenisation methods gave very similar results: a temperature difference on yearly basis of +0.8 °C for the first break in 1919 and of -1.0 °C for the break in 1930.

Minimum and maximum temperature was also homogenised and results were downscaled using daily adjustments.

3.3.3. ZAMG-I

<u>Homogenisation</u>

The main objective of ZAMG-I was the homogenisation of snow data (fresh snow), observed from 1895 to 2000 at 62 stations across the Tyrol and collected by the famous Climatologist Franz Fliri. The "Fliri"-dataset was quality controlled by means of an area-visualization of fresh snow, which simply shows the complete observing area. With the aid of these snow maps, every winter was classified by its general characteristics (strength of winter and direction of stream for main snow fall, e.g. NW or SE). Unreliable data was detected and removed.

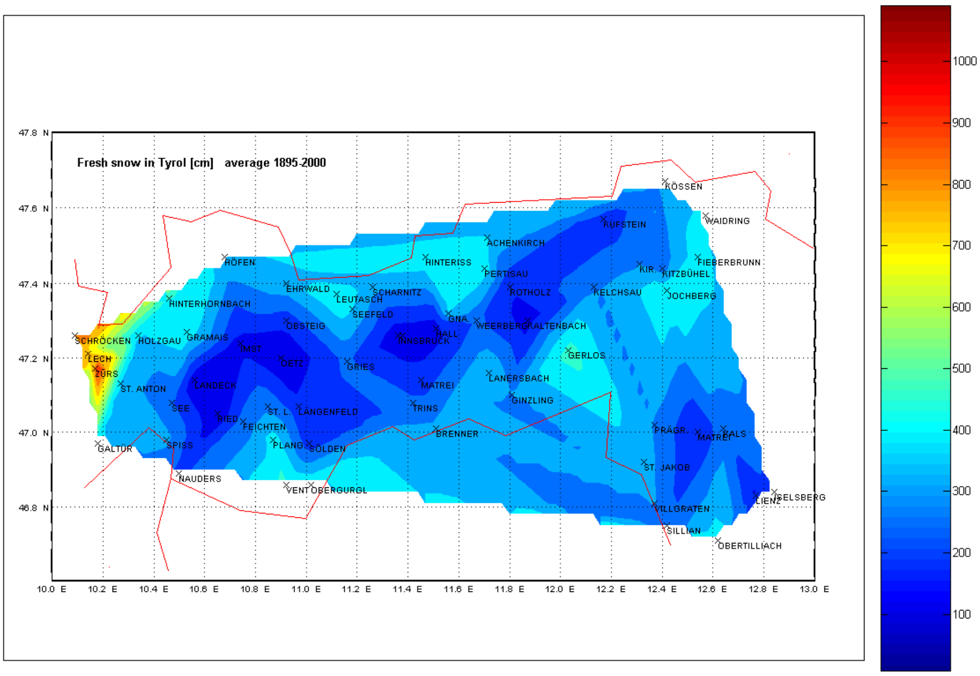


Figure 28. Average fresh snow over Tyrol observed from 1895-2000 by 62 selected stations; area-plots were used for Quality control of the "Fliri"-dataset

Fresh snow was observed on a daily basis. For the homogenization process monthly sums were calculated and winter-sums were used for quality control to avoid bias through common climatological fluctuations of fresh snow data.

A common problem of long-term observations is that a high number of data is incomplete or missing. From the 62 stations over 105 years not even one station had a complete set of data. 5568 data points (85%) were existing and 962 (14%) were missing due to different reasons. Many observations were lost because of data transfer to Germany during Second World War. The whole archives burned down at the end of the war and data was totally lost. 401 (6%) data points were selected as “unreliable” and therefore they were removed. The final homogenisation process had a base of 5167 data points (79%).

For the homogenisation process of the long-term series ZAMG-I operated with HOCLIS (described in Auer et al., 2001 and improved in Auer et al., 2005, chapter 3.3.1). For snow data no smoothing was performed. Homogenisation has been performed within regions of similar precipitation patterns as well as similar altitude levels to conserve regional snow pattern characteristics.

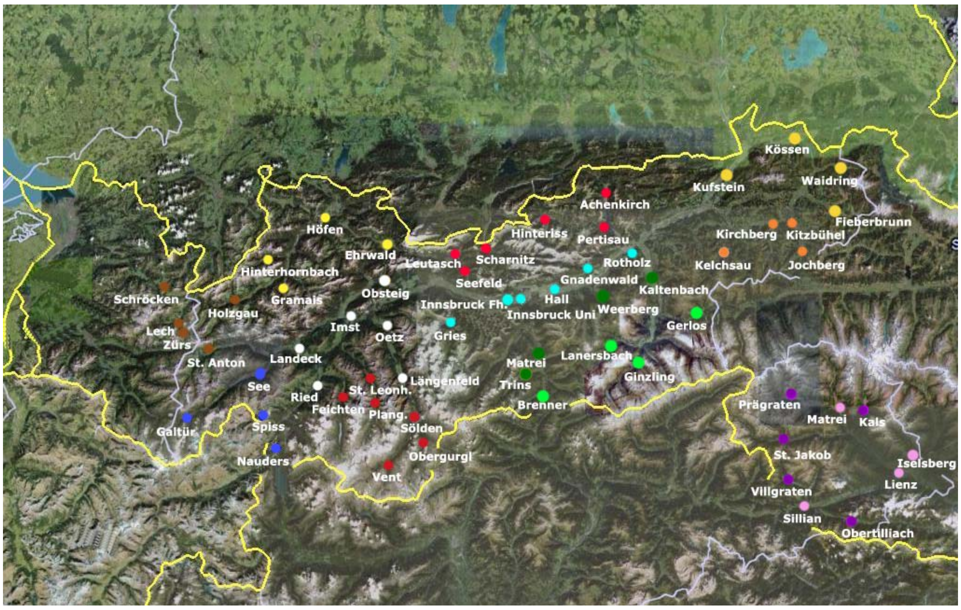


Figure 29. Regional classification of snow data in Tyrol: stations with same colours represent regions with similar precipitation patterns and/or similar altitude levels.

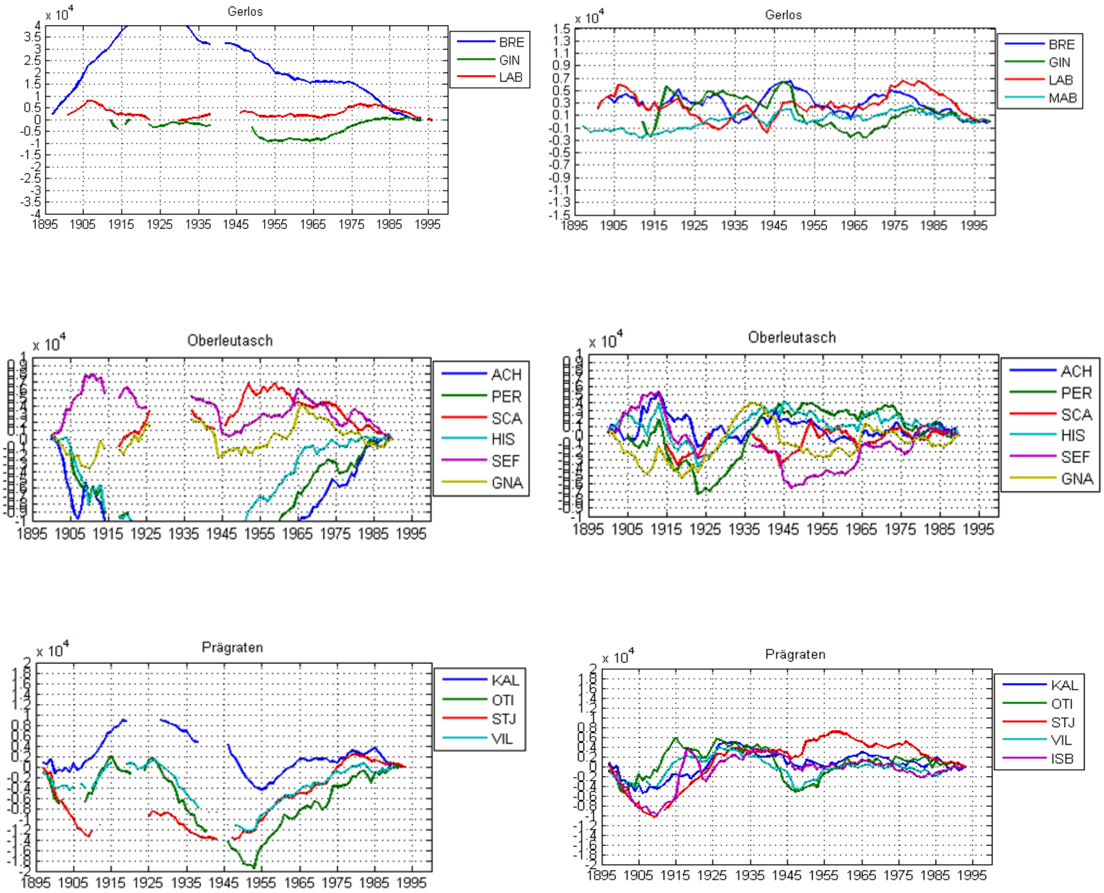
Homogenisation of snow data is a complex field. Deviations between stations of the same region caused by climatological reasons (e.g. different precipitation patterns affected by varying characteristics of miscellaneous winters) can be a strong confounding factor and it is hard to extract them from deviations caused by non-climatological effects. For this reason, ZAMG-I tried to find and eliminate only the main break points to keep natural climatological effects as untouched as possible. To combine the whole dataset a “jumping station” was selected. Data of this station was implicated in the homogenisation process of the following region as a homogenous reference dataset.

break points and reference stations - HOCLIS - FLIRI										
region	**colour**	**station (jumping)**	**bp 1**	**ref**	**bp 2**	**ref**	**bp 3**	**ref**	**bp 4**	**ref**
Inntal	cyan	Hall	1955	IBU	1923	GNA				
Inntal	cyan	InnsbruckUni	1965	GRI						
Inntal	cyan	InnsbruckFlug	1971	ROT						
Inntal	cyan	Rotholz	1977	IBF	1953	GNA	1936	GNA		
Inntal	cyan	Gnadenwald (j)	1972	IBF	1961	GRI	1944	GRI	1935	GRI
Inntal	cyan	Gries	1923	HAL						
Karwendel	red	Achenkirch	1945	GNA(j)						
Karwendel	red	Hinteriss	1955	GNA(j)	1944	ACH				
Karwendel	red	Pertisau	1945	GNA(j)						
Karwendel	red	Scharnitz								
Karwendel	red	Oberleutasch (j)	1965	GNA(j)						
Karwendel	red	Seefeld	1910	ACH						
Ausserfern	yellow	Höfen	1977	GRA	1969	GRA	1955	LEU		
Ausserfern	yellow	Ehrwald	1982	GRA	1953	LEU(j)				
Ausserfern	yellow	Hinterhornbach	1979	HOE	1924	HOE	1913	HOE		
Ausserfern	yellow	Gramais (j)	1955	LEU(j)	1924	LEU(j)				
Arlberg	brown	Holzgau (j)	1979	STA						
Arlberg	brown	Schröcken	1979	GRA(j)						
Arlberg	brown	St. Anton/Arlberg	1965	HOL	1955	HOL				
Arlberg	brown	Lech	1976	ZUE						
Arlberg	brown	Zürs	1987	GRA(j)	1979	GRA(j)	1961	GRA(j)		
Paznaun	blue	See im Paznaun								
Paznaun	blue	Nauders (j)								
Paznaun	blue	Galtür	1989	NAU	1987	HOL(j)	1933	HOL(j)		
Paznaun	blue	Spiss								
Pitz/Ötztal	dark red	Feichten	1965	NAU(j)						
Pitz/Ötztal	dark red	St. Leonhard								
Pitz/Ötztal	dark red	Sölden								
Pitz/Ötztal	dark red	Plangeross (j)								
Pitz/Ötztal	dark red	Vent	1965	NAU(j)						
Pitz/Ötztal	dark red	Obergurgl	1964	NAU(j)						
Oberland	white	Oetz								
Oberland	white	Imst	1983	OBS						
Oberland	white	Landeck								
Oberland	white	Ried im Oberinntal								
Oberland	white	Obsteig	1964	RIE						
Oberland	white	Längenfeld (j)	1964	LAN						
Tux/Gschnitz	dark green	Kaltenbach	1955	WER						
Tux/Gschnitz	dark green	Weerberg	1952	LAE(j)						
Tux/Gschnitz	dark green	Matrei am Brenner (j)	1961	WER						
Tux/Gschnitz	dark green	Trins	1972	LAE(j)	1945	LAE(j)				
Zillertaler	green	Ginzling (j)								
Zillertaler	green	Lanersbach	1953	MAB(j)	1908	MAB(j)				
Zillertaler	green	Gerlos	1977	MAB(j)	1967	BRE	1953	MAB(j)	1924	MAB(j)
Zillertaler	green	Brenner	1990	MAB(j)	1975	MAB(j)				
Osttirol/low		Lienz	1985	SIL						
Osttirol/low	l-violett	Matrei inOsttirol	1924	LIE						
Osttirol/low	l-violett	Sillian	1932	ISB						
Osttirol/low	l-violett	Iselsberg (j)	1983	SIL						
Osttirol/high	violett	Prägraten	1982	VIL	1953	KAL	1926	OTI		
Osttirol/high	violett	Kals (j)	1955	VIL	1946	VIL				
Osttirol/high	violett	Villgraten								
Osttirol/high	violett	St. Jakob im Def.	1909	ISB(j)						
Osttirol/high	violett	Obertilliach	1984	VIL						
Kitzbühler	red gold	Kitzbühel	1949	KEL	1912	KIR				
Kitzbühler	red gold	Kelchsau (j)	1952	KIZ						
Kitzbühler	red gold	Kirchberg	1969	KIZ	1948	KIZ				
Kitzbühler	red gold	Jochberg	1976	KEL	1969	KEL	1951	KIR	1912	KEL
Unterland	gold	Kufstein								
Unterland	gold	Kössen								
Unterland	gold	Waidring	1953	KEL	1938	KEL				
Unterland	gold	Fieberbrunn								

Figure 30. Detected break points operated with HOCLIS and reference dataset for homogenisation

Detected break points of inhomogeneous datasets were corrected with computed correction quotients using HOCLIS software tools. For snow data, quotients were used instead of differences to avoid negative data points. Missing data was filled with the help of another HOCLIS tool. Missing data points were filled only in the case of existing data points before and after the gap.

For all 62 stations the same homogenisation process was applied. Every single station had its own characteristics and was slightly different to handle. Also, the performance of the homogenisation procedure turned out to be different for each station. Summing up, after comparing the quality of the results with the raw data, homogenisation process positively affected the whole dataset.



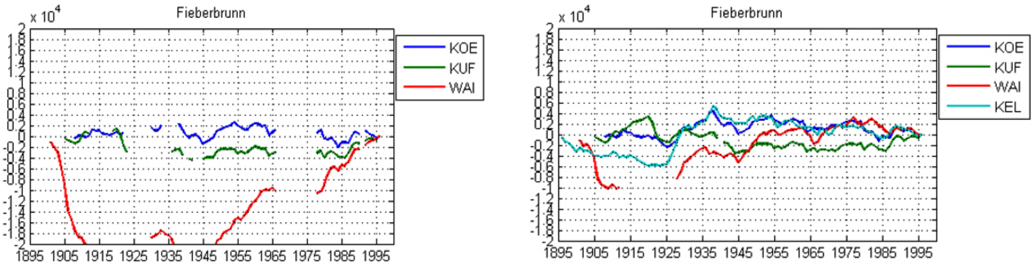


Figure 31. Craddock curves of HOCLIS homogenisation processing: left graphs: stations Gerlos, Oberleutasch, Prägraten and Fieberbrunn before homogenisation; right graphs: after homogenisation; MAB, GNA, ISB and KEL were homogenous "jumping stations" from a neighbouring region

Missing data around 1915 and 1940 was almost fully completed. Figure 32 shows the whole dataset after homogenisation and completion. Green boxes mark entirely completed data points, orange marks represent removed or missing data which was not completed.

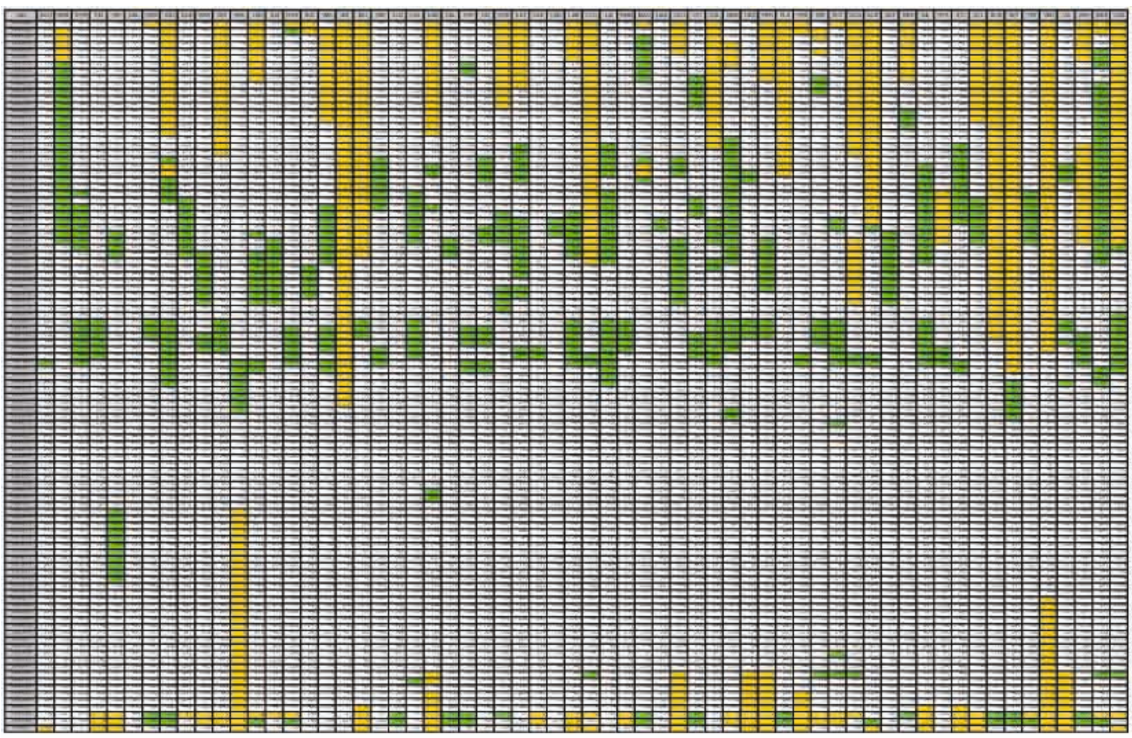


Figure 32. Completed and homogenous data-set, 62 stations in columns, 105 years in rows: Green boxes show a completed value, orange boxes are sign of remaining missing data

After homogenisation and completion, 5746 data points (88%) had a value. This means, 598 data points have been filled (9%) and 764 data points (12%) remained with no value.

3.4. Metadata Management

Metadata rescue is essential to correctly homogenise a long-term dataset. On the one hand, it identifies breakpoints in the series, on the other hand a systematic metadata set may be used for the validation of is the statistically detected breakpoints

3.4.1. ARPA Lombardia

The recovered metadata

- are an essential information to better identify data in space and time: the name of the station, data source, the last known geographical position. Those data refer to the last known information in time about the site;
- are additional very useful information, however not always available regarding the history of the station: the station's features (the equipment in terms of instrumentation, the frequency of the measurements, the observer's name…), the station's distance from the ground, the station's owner, the station's positions in time, the map of the surroundings of the station in time, old and new photos in time, etc. This kind of information needs to be referenced in time, or at least sorted in temporal order.

All this information, where available, was put in a text file, in which also the homogenisation parameters were written. The climate indexes are also considered as metadata.

A structured database was built with all collected information. This metadata-base is a part of the secular series database, and all the information, both quantitative (data) and qualitative (metadata), can be retrieved and visualized through a query.

The main problem was dimensioning the database attributes: the risk is to have a huge unique table with information too general to be easily selected, or, on the other side, to have too many small tables with only sparse information inside. Looking at the kind of metadata available for all the stations we chose a compromise, favouring the more complete metadata set for all the stations. This feature makes the ARPALombardia's FORALPS meta-database a specific product of this metadata collection. Of course, a better metadata recovery or availability could provide a more complete and different meta-database.

3.5. Methods developed for data reconstruction

3.5.1. UniTN

A problem specifically affecting series composed from measurements taken before the introduction of modern standards about observation timing and instruments (e. g. maximum and minimum thermometers) is the availability of only one daily observation, often taken at varying hours. Even when the observer used to record at least the daily hour at which measurements were taken, the effective diurnal timing of measurements have to be reconstructed if the adopted timing system was an older one. Indications about the state of the weather at the time of observations, which usually were recorded as side information as well, are a very useful reference to classify the days into some weather categories.

Within FORALPS the Partner UniTN has developed a method to estimate daily temperature maxima and minima when only such single daily readings are available, taking advantage of all the available information. The method requires the availability of a representative diurnal temperature cycle for each weather category, determined for instance using a sample of recent high frequency temperature measurements taken in the same area (of course, in more recent times). Based on linear regression, a best fit line is obtained, which provides the basis for the relationship between the single-hour readings and daily extremes. The fitting function's parameters provide the basis for the evaluation of maxima and minima from single daily readings. The method provides also an estimate for the intrinsic error of the estimate. The method has been first applied to the reconstruction of the temperature series of Verona (1741-2006). More detail can be found in Appendix 5: A method to estimate daily maxima and minima based on single daily air temperature readings by Andrighetti et al..

4. Examples for FORALPS Data Applications and Data Analyses

4.1. ZAMG-W

4.1.1. Calculation of WMO Climate Change Indices

The Calculation of "Climate Change Indices" offers a broad spectrum of parameters appropriate for Climate Impact studies. Originally these indexes were defined by the CCl/CLIVAR Expert Team on Climate Change Detection, Monitoring and Indices. A detailed description can be found on the CLIVAR web page: http://www.clivar.org/organization/etccd/. This expert team has recommended a number of descriptive indices to represent changes in the mean and extremes of climate and a number of research projects adopted these definitions to describe regional climate change, e.g. EMULATE or ECA&D. ZAMG-W decided to adopt these indices as well. As an overall result it may be concluded that the uniform Alpine temperature increase (Auer et al., 2007) caused regionally different features of precipitation based "Climate change indices". Climate Change based on daily temperature series in general tends to reflect the warming, with regionally stamped features. Trends were calculated for the last 50 years (1957-2006) to allow also shorter stations to be included into the general results.

- A general temperature increase took place over all of Austria during the last 50 or 100 years. The regional differences have been rather small. Summer curves show a warming in two steps, one until 1950 and one in the last recent decades since the 1980ies. Winter shows the largest temporal variability compared to spring, summer and autumn. Embedded in the long-term warming marked maxima appear around 1920, 1980 and 2000.

- During the last 50 years frost days have decreased all over Austria. In particular, the highest Alpine areas experienced a remarkable ≈30 day decrease, concentrated in the “warm season”; the most significant changes for the low level stations occurred from autumn to spring.
- Growing Season Length (GSL) has been increasing all over Austria up to 1 month. Increase of GSL was even noticed at high elevation Alpine areas where vegetation could not develop up to now.
- Diurnal temperature range has been rather stable during the 20th century and afterwards. There are only small increases or decreases around 0°C to be seen. However impressing displayed (in Figure 36) the reduced DTR in high Alpine regions compared to inner-alpine valleys.
- Tropical nights have been increasing during the last 50 years, and some regions of Austria have been recently concerned by this issue.

- 20th century and afterwards precipitation time series show a high spatial and temporal variability. Variation coefficients vary around 15%, and for the last 50 years we find stations with increases in precipitation sums in parallel with stations exhibiting decreasing precipitation sums. Trends sometimes are rather high, however not significant due to the strong variability in time.
- The SDII (Simple Daily precipitation Intensity Index) shows strong oscillations during the century without any significant trends due to the high variability. Changes of SDII are not representative for a larger region.
- Changes in dry spells are distributed unevenly within the Austrian territory. Highest values occur in the South and the East. For the maximum lengths of a dry spell which has been defined being the maximum number of days with a precipitation amount below 1 mm an equal picture may be expected. Changes during the last 50 years indicate intensification in the South and the East whereas in the western parts of Austria the maximum length of a dry spell has been deceasing. The variability from year to year is rather high.
- Regionally different results were found as well for extreme high precipitation events and the precipitation frequencies.

ID	NAME	Long.	Lat.	Alt.	NUTII	Remarks
ADM	Admont	14.45	47.57	646	AT22	
BBL	Bad Bleiberg	13.66	46.62	907	AT21	
BGA	Badgastein	13.13	47.12	1100	AT32	
BGL	Bad Gleichenberg	15.90	46.87	303	AT22	
BIL	Bad Ischl	13.63	47.72	469	AT31	
BMU	Bruck/Mur	15.26	47.41	482	AT22	
*BRE	Bregenz	9.73	47.50	424	AT34	small densely built up area and larger areas of suburban character between the eastern shore of the large Lake Konstanz (Bodensee, 396m asl.) and the steep slopes of Pfänder (1060m asl)

BST	Bernstein	16.26	47.35	600	AT11	
DLB	Deutschlandsberg	15.22	46.83	410	AT22	
EIS	Eisenkappel	14.59	46.49	623	AT21	
EST	Eisenstadt	16.54	47.85	184	AT11	
FEL	Feldkirch	9.62	47.27	440	AT34	
FEU	Feuerkogel	13.72	47.82	1618	AT31	
*FLA	Flattach	13.12	46.93	736	AT21	Inner alpine small village station in the Möll valley south of the Alpine main crest
FRE	Freistadt	14.50	48.52	548	AT31	
*GRA	Graz	15.45	47.08	377	AT22	at the SE border of the Alps, urban station
HEI	Heiligenblut	12.85	47.03	1242	AT21	
*INN	Innsbruck	11.38	47.27	609	AT33	In large W-E Inn valley, densely built-up area, suburban environment, with slowly increasing urbanisation.
KAL	Kals	12.63	47.00	1350	AT33	
*KLA	Klagenfurt	14.33	46.65	459	AT21	situated in the centre of one of the most pronounced inner-alpine basins, since 1939 the station is located at the airport.
KOL	Kollerschlag	13.84	48.61	725	AT31	
KOR	Kornat	12.89	46.69	1047	AT21	
*KRE	Kremsmünster	14.13	48.05	389	AT31	in rural environment without much development in land use and urbanisation.
KUF	Kufstein	12.17	47.58	495	AT33	
LAD	Landeck	10.57	47.13	785	AT33	
LAG	Langen	10.12	47.13	1218	AT34	
LIN	Linz	14.28	48.30	263	AT31	
LIZ	Lienz	12.81	46.83	659	AT33	
MST	Millstatt	13.58	46.80	791	AT21	
NAU	Nauders	10.50	46.90	1360	AT33	
PAK	Patscherkofel	11.46	47.21	2247	AT33	
RAD	Radstadt	13.45	47.38	845	AT32	
*RAU	Rauris	12.99	47.22	934	AT32	inner-alpine valley station
RDT	Radenthein	13.70	46.78	685	AT21	
REI	Reichenau/Rax	15.84	47.70	485	AT12	
RET	Retz	15.95	48.77	242	AT12	
RIE	Ried im Innkreis	13.48	48.22	435	AT31	
*SAL	Salzburg	13.00	47.80	450	AT32	at the mouth of the Salzach valley from the Alps into the relatively flat northern foothills, recent position being at the airport.
SAN	St. Andrä im Lavanttal	14.83	46.77	404	AT21	
SCH	Schmittenhöhe	12.73	47.33	1973	AT32	
SCK	Schöckl	15.47	47.20	1436	AT22	

SEK	Seckau	14.78	47.28	874	AT22	
*SON	Sonnblick	12.95	47.05	3105	AT32	High Alpine mountain observatory
SPO	St. Pölten	15.61	48.18	285	AT12	
SSB	Mariazell	15.31	47.79	872	AT22	
TAM	Tamsweg	13.80	47.13	1012	AT32	
VIA	Villacher Alpe	13.67	46.60	2160	AT21	Villacher Alpe is a mountaintop site 70km S of the main ridge of the Eastern Alps, remote from populated areas
VIL	Villach	13.87	46.62	495	AT21	
WAI	Waidhofen/Ybbs	14.76	47.95	421	AT12	
WGA	Windischgarsten	14.30	47.73	596	AT31	
*WIE	Wien-Hohe Warte	16.35	48.22	209	AT13	in the transition zone from the NEmost hills of the Alps (tops of 400 to 600m asl) to the flat plains of the “Wiener Becken”, in the sub-urban of the City of Vienna.
WMA	Wien Mariabrunn	16.14	48.12	236	AT13	
WRN	Wiener Neustadt	16.21	47.81	285	AT12	
ZEL	Zell am See	12.78	47.32	766	AT32	
*ZWE	Stift Zwettl	15.20	48.62	500	AT12	located at the hilly plateau of the “Waldviertel”, rural surrounding hills are some 100m higher than the measuring site which makes the site very typical for shallow layers of cold air
*	Selected results are presented below					

Table 1. Station network for the analyses of climate change and climate variability in Austria

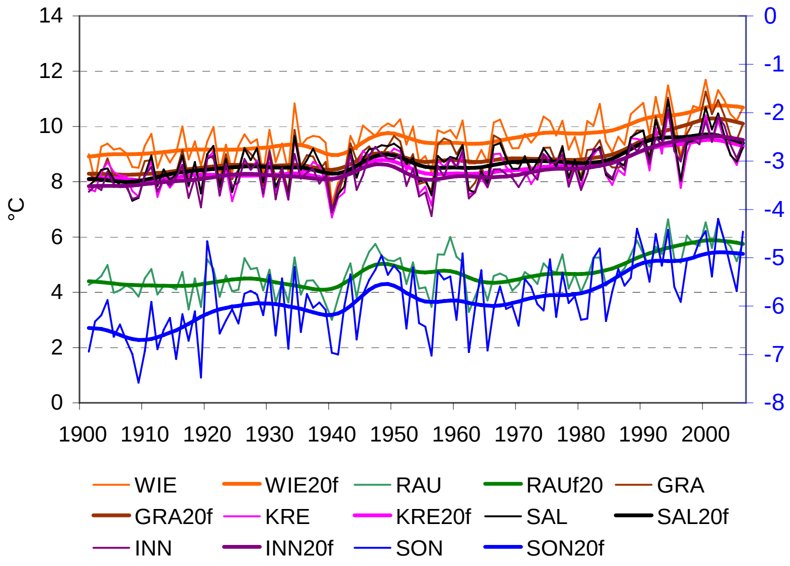


Figure 33. Time series of the annual mean temperature for single stations representing different regions (for Sonnblick use the y-axis on the right, all others left y-axis).

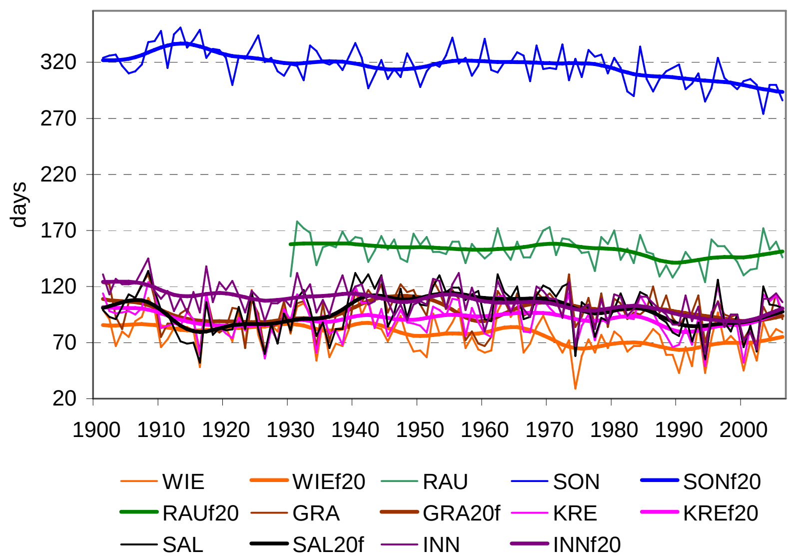


Figure 34. Time series of the annual number of frost days for single stations representing different regions.

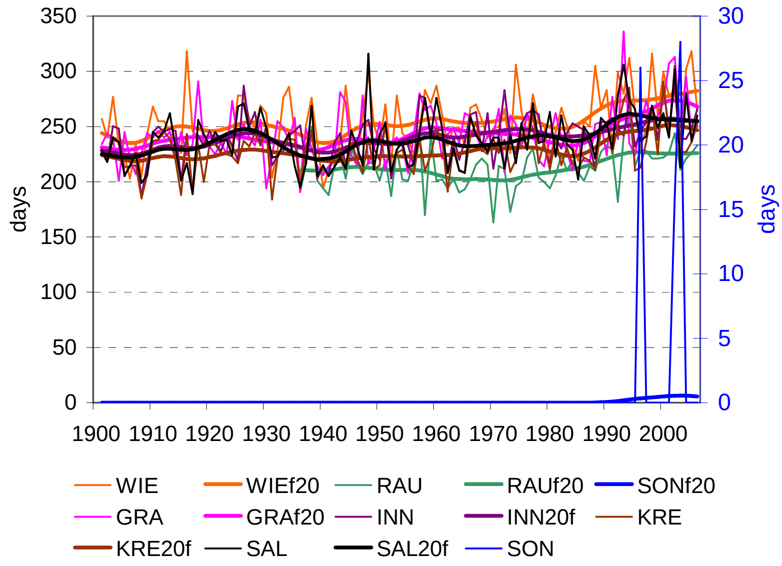


Figure 35. Time series of the annual Growing Season Length (GSL) for single stations representing different regions.

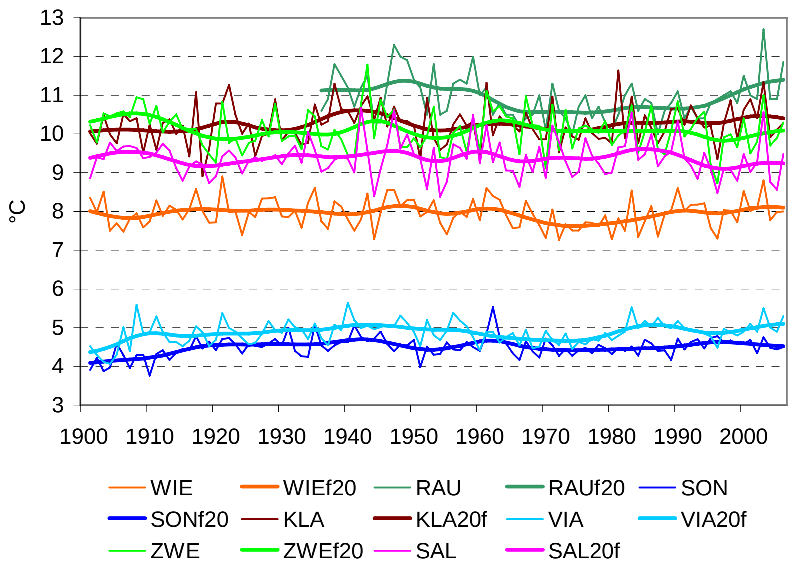


Figure 36. Time series of the annual diurnal temperature range (DTR) for single stations representing different regions

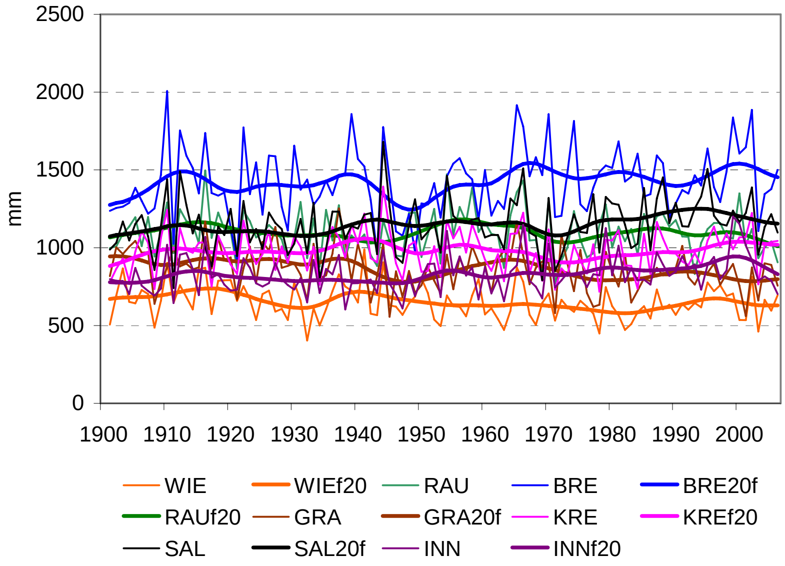


Figure 37. Time series of the annual precipitation sum for single stations representing different regions.

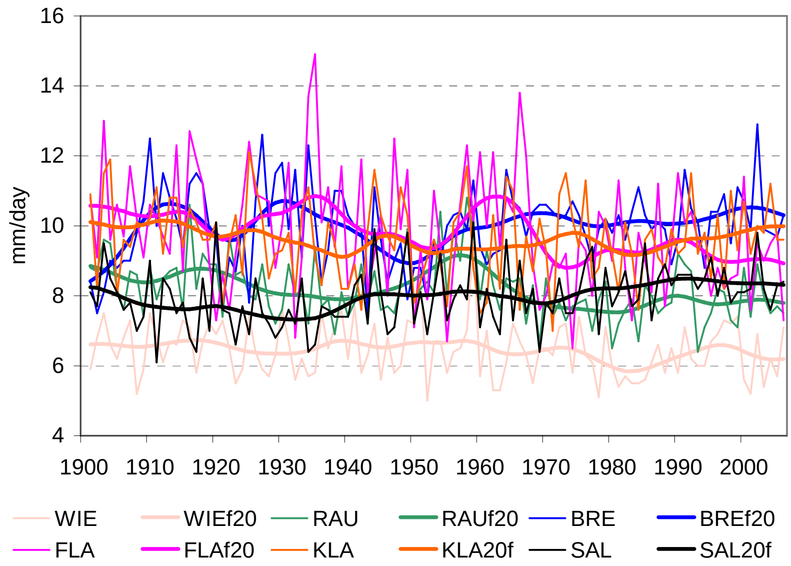


Figure 38. Time series of the annual simple daily precipitation intensity index (SDII) for single stations representing different regions.

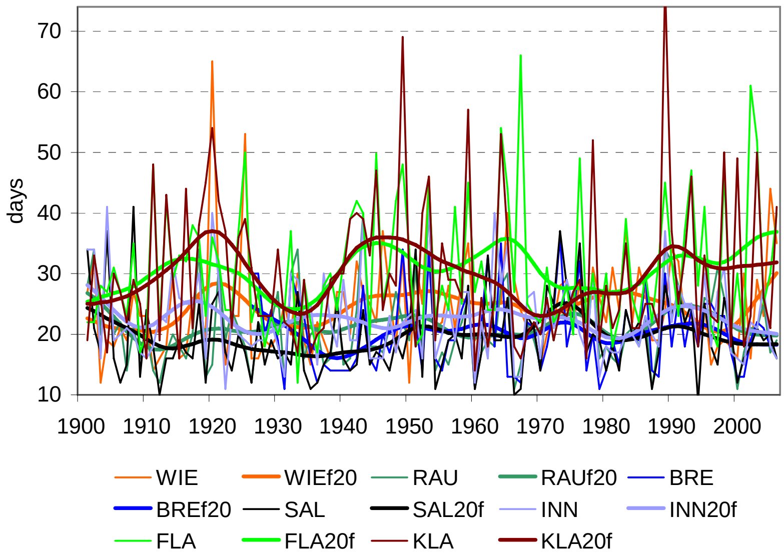


Figure 39. Time series of the maximum lengths of an annual dry spell for single stations representing different regions.

4.1.2. Percentage of solid precipitation on the total precipitation

In the Austrian data management routines the share of solid precipitation on the total precipitation has been introduced as calculated climate parameter. It is calculated from daily precipitation using observers' information on the precipitation type (snow, rain, hail, etc.) or – if no such information is available – on temperature records. In the Austrian Alps most of the solid precipitation is falling as snow, only a marginal percentage comes from hail during the warm season. The percentage of solid precipitation is in close relation to temperature: if temperature changes the share of solid precipitation may change as well. However, in finding a reasonable model we have to deal with a non-linear relationship (tanh model) between temperature and snow fall. The method for such a sensitivity approach has been described first by Hantel et al., 2000 for snow cover duration. In 2005, Auer et al. used the tanh – function to model the number of frost days.Now it has been used to estimate long-term snowfall changes. This is a promising additional snow parameter to the directly measured snow fall series with their enormous variability in space and time.

This Climate Change Index is a typical one for use in practical applications. Due to its strong relationship to temperature it can provide information at much higher spatial resolution than snow itself (with its small spatial representativity) and via total precipitation it can be re-converted into snow fall amount (mm). Here we show some examples for selected skiing regions.

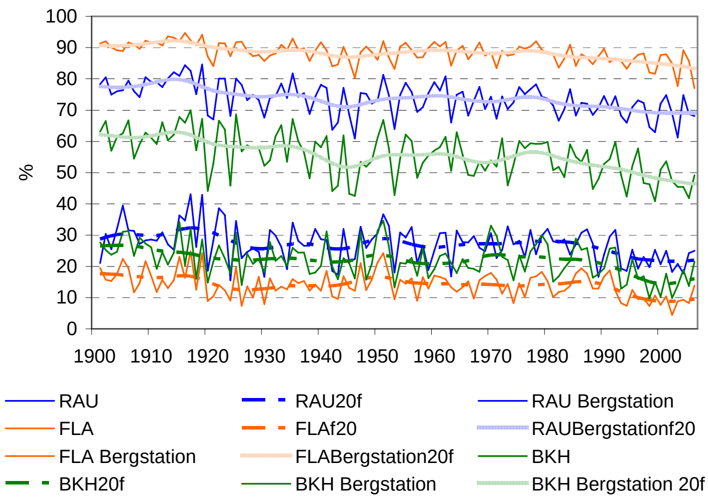


Figure 40. Time series of the share of annual solid precipitation on the annual total precipitation for three skiing locations. For each location the curves represent two different elevations (town and highest altitude of skiing area).

	RAU	RAU Berg	FLA	FLA Berg	BKH	BKH Berg		
1957-2006	-5.0	-6.0	-5.5	-5.8	-7.4	-8.9		%

Table 2. 50yrs change (1957-2006) of the share of annual solid precipitation on the annual total precipitation for three skiing locations. RAU: Rauris, RAU Berg: Rauris at the altitude of the top station of the ski lift, FLA: Flattach, FLA Berg: Flattach at the altitude of the top station of the ski lift, BKH: Bad Kleinkirchheim, BKH Berg: Bad Kleinkirchheim at the altitude of the top station of the ski lift.

In parallel to the increase of temperature the share of solid precipitation has been remarkably decreasing during the 20th century. The calculated negative trends of the last 50 years vary between 5 and 10 %, and are slightly higher in the high-elevation Alpine areas. To understand this, one has to investigate the seasonal dependence as well. Up to now, practically no changes occurred in winter in the Alpine areas with altitudes above 3000 m. The solid precipitation share was rather stable and close to 100%. However, lower altitude locations (around 1000 m) lost about 10% during the last 50 years. In summer the situation is opposite. In summer normally there is no snowfall in the lower regions; with increasing altitude, however, the summer snow has been reacting more and more to the rise in temperature and experienced a loss of solid precipitation by 15%. In spring and autumn altitudes between 1500 and 2000 m are those concerned mostly.

4.1.3. Interpolation and Regionalization of daily snow depth datasets for Austria – Comparison of two time slices (1896-1916 vs. 1980 – 2000).

A newly created historical time slice (1896-1916) with more than 900 stations has been compared with the recent period 1980 -2000. As an overall result it can be stated: A significant decrease (negative trend) in the South of Austria has been observed. A simultaneous increase in temperature and decrease in precipitation led to small fresh snow amounts, and finally to a decrease of daily snow depths. An extended report including some interpolation techniques as well statistical tests is given in Appendix 6 provided by Jurkovic et al.

4.2. ARPALombardia

A huge work of data rescue from several sources, and of data organization, now enables ARPA Lombardia to count on 20 long-term daily series of rainfall and 11 series of temperature in the Greater Lombardy Area (GLA, 44 to 47_N, 7 to 12_E). This dataset can be considered representative for the whole region in space and time.
All the data and metadata collected (raw, validated and homogenized) are stored in a database with geographical information. The same system also stores calculated indices. With this tool the time series are easily managed, and the datasets have been used to provide some preliminary analysis of last century's climate in the GLA.

Depending on time resolution (daily, monthly, seasonal or annual) the data features are different, and so are the meaning of the indices: they can show trends in time, changes in the extremes or persistence of some weather conditions (wet or dry periods, heat waves or cold waves).

Five stations with long term daily series have been chosen with 100 years of homogeneous data: Mantova, Milano, Pavia, Lugano, Locarno. Twenty seven indices based on daily data were calculated with a common tool written in R language (Rclimdex, available on the web). The most significant ones for temperature (GSL - Growing season Length; TR20 - Tropical nights; ID0 - Ice days; FD0 - Frost days) and precipitation (R10 - Number of heavy precipitation days; R20 - Number of very heavy precipitation days; CDD - Consecutive dry days; CWD - Consecutive wet days) were chosen.

The analyses show significant signals in the temperatures series while in rainfall series the signals are not so clear (as the following figures show).

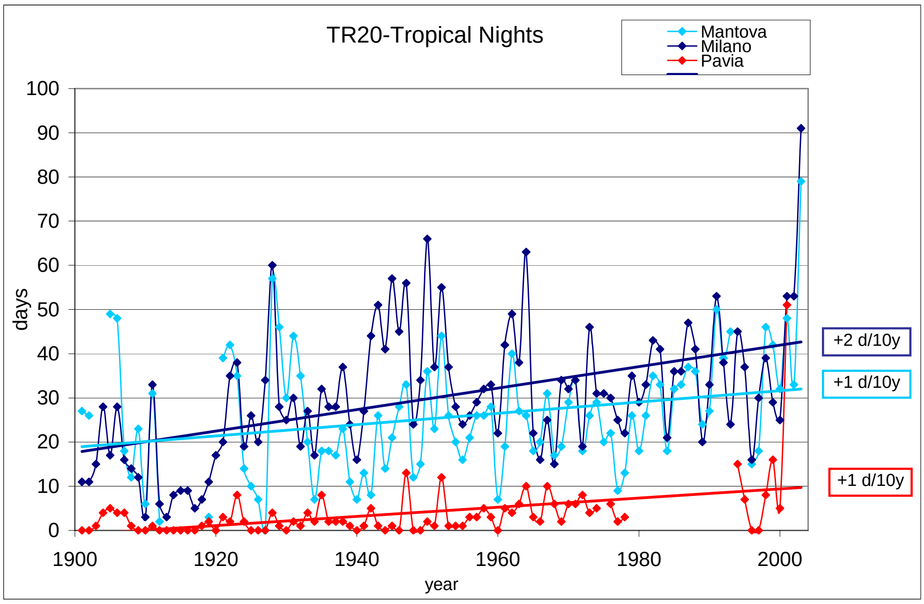


Figure 41. TR20 - number of tropical nights - Annual count of days when TN (daily minimum temperature) is more than 20°.

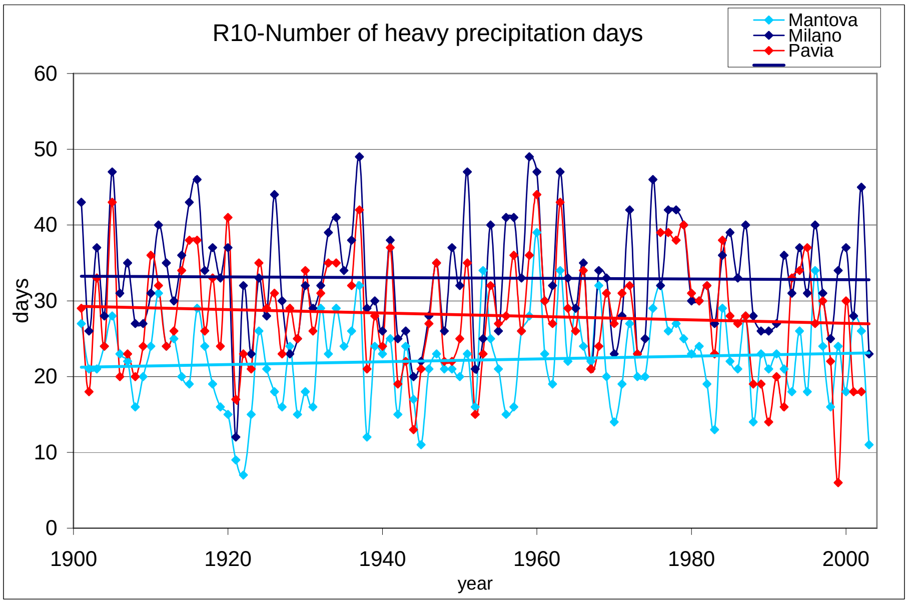


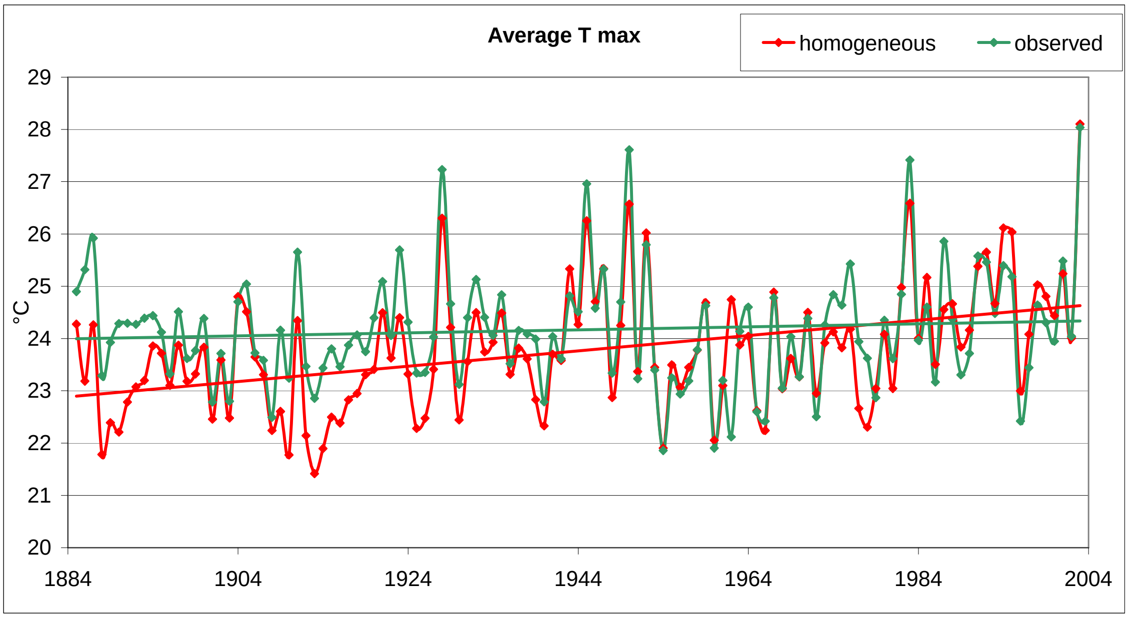
Figure 42. R10 - number of heavy precipitation days - Annual count of days when daily precipitation is equal or more than 10 mm.

The indices based on daily data show a general warming process, more marked in the last half century. Nothing significant can be said about rainfall, neither on the total yearly amount nor on the event intensity.

Other simple indices based on monthly, seasonal and annual data were calculated for four stations representative of Lombardy's climatological areas: Sondrio (Alpine), Bergamo (Pre-Alpine), Milano (high plain), Mantova (low plain and Appennines). The indices were:

- Tmax: the temperature of the warmest month of the year;
- Tmin: the temperature of the coldest month of the year;
- Tmean: the average annual temperature;
- Taveragemax: the average Tmax among all the stations;
- Taveragemin: the average Tmin among all the stations;
- Taveragemean: the average Tmean among all the stations;
- MaxP: the precipitation of the rainiest month in the year;
- MinP: the precipitation of the less rainy month in the year;
- TotP: total precipitation of the year;
- AvTotP: the average TotP among all the stations.

All the indices were calculated using the homogeneous series and the observed ones for all the stations. A comparison between the linear trends in the indices calculated using the homogeneous series and the observed ones was also done.



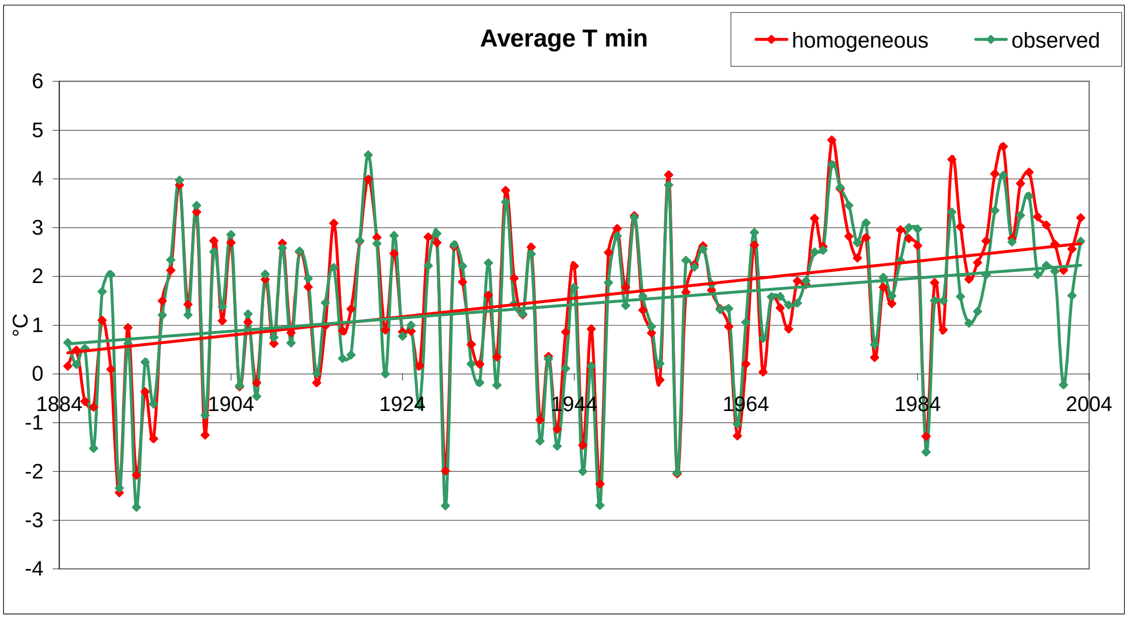


Figure 43. Mean daily maximum and minimum temperature (average of four stations)

The first results show some interesting points:

1. The climate isn't stationary, at least in the last half century. Strong signals can be detected in temperature data, which is increasing. In rainfall observations the signals are not so clear.
2. The comparison between homogeneous and observed series shows that: temperatures are sensitive to homogenisation, and some trends are increased by the process; rainfalls aren't so sensitive, in fact the difference between the calculated trends is lower than the measuring precision.
3. Only good continuous measurements provide good climate analysis.

4.3. EARS

4.3.1. Long-term climate reconstructions and analyses in Ljubljana

Instrumental measurements in Ljubljana have begun in March 1850. Between 1850 and 1948 the meteorological station changed seven times its location (Figure 44).

- In the period March 1850–December 1852, the meteorological measurements were taken in the railway station of Ljubljana (eastern part of the building).
- From January 1853 till the end of June 1895 the meteorological measurements and observations were taken in Prečna ulica.
- Different location from July 1895 till the mid January 1919
- And from 16th of January 1919 till the end of December 1924 the location of the meteorological station was in the building "k.k. Oberrealschule". The location of instruments changed several times within the building itself. But the location of thermometers was not appropriate, and parallel measurements of temperature

were established and taken in Šiška (metadata for this location was lost) and in the Women's Hospital in the period of March 1922 till the end of September 1948. On the 13th of June 1922, the rain gauge was moved from the roof of the school into the schoolyard.

- From December 1895 till July 1919 measurements of precipitation were taken in Levstik gasse. In that period snow cover was measured only on this location.
- In the period from January 1921 till the end of 1925 the location of shelter for meteorological instruments was in the Geographical Institute (second floor of the building, with view on Gosposka Street).
- From January 1926 till 28th of December 1947 the location was in the University, in several different locations of the building.
- From 28th of December 1947 on the location of meteorological observing site has been in Ljubljana Bežigrad. The problem are the changes in the surroundings of the station.

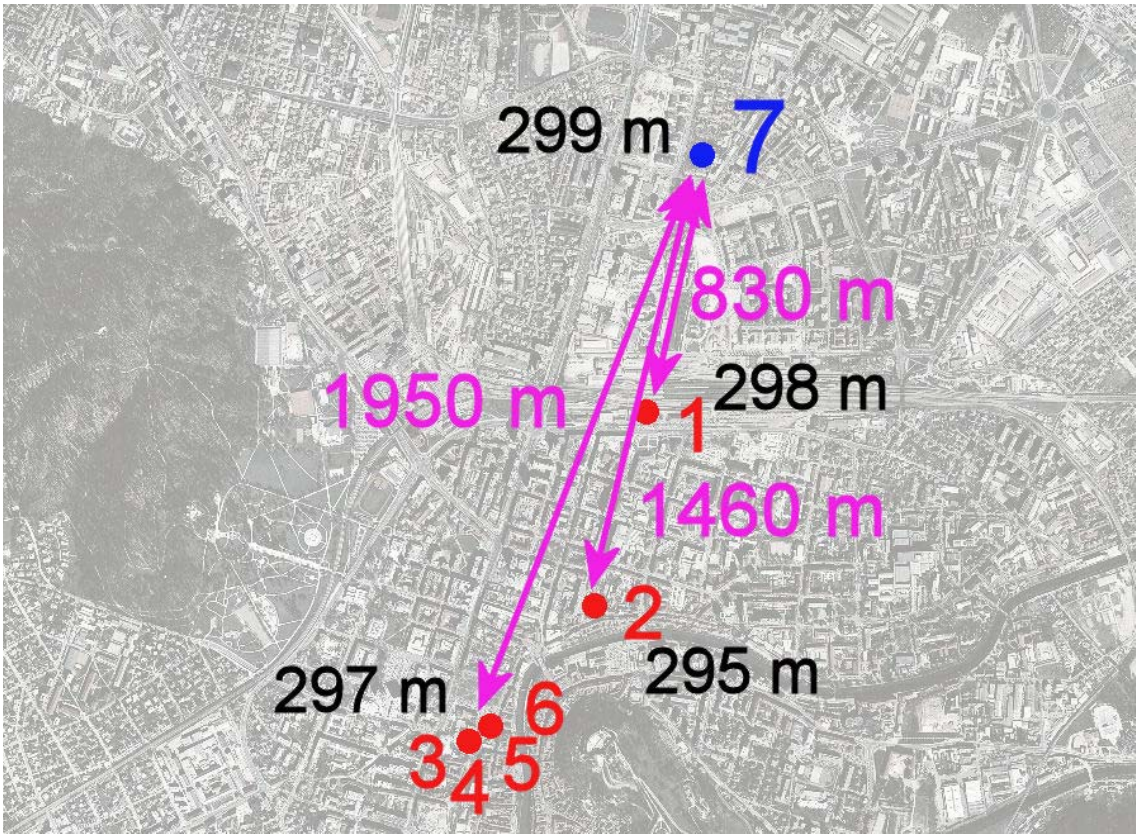


Figure 44. Seven different locations of Ljubljana meteorological station.

Problems in reconstructing and analysing the data are:

- seven re-locations of the meteorological station (from 1850 till 1948),
- insufficient documentation of metadata,
- changes in station's surroundings,
- non-standard observation times,

- non-standard measurement units (Paris line for precipitation).

Climate indices for Ljubljana were calculated on original data series and on homogenised data series. Results were quite different. The number of frost days and ice days has decreased quite considerably, while the number of summer days has increased. According to linear trend, the average annual temperature in Ljubljana has raised for 2.2 °C during the last 140 years (original data: 1.7 °C). The long-term average on homogenised data is 0.2 °C lower than the original one.

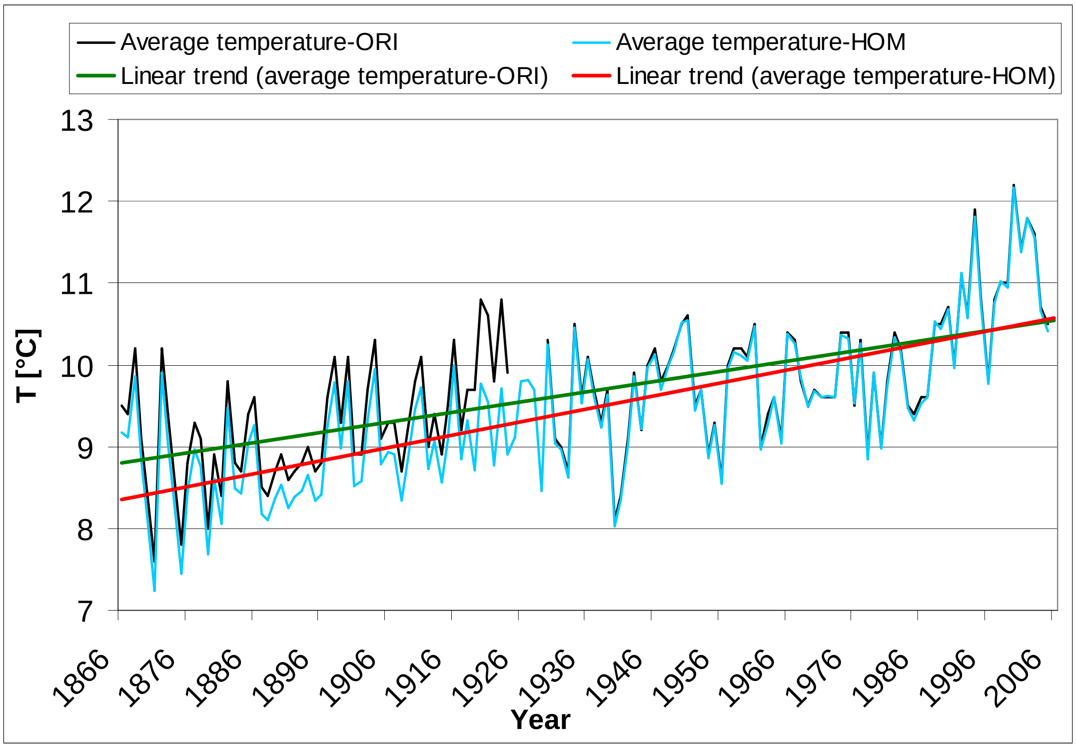


Figure 45. Original and homogenised temperature with linear trend in Ljubljana.

4.3.2. Flood event in Železniki

On the 18th of September 2007 a huge natural disaster happened in Železniki, when the Sora river flooded the whole village. The event was very sudden, one person died and great financial loss was suffered.

Figure 46. River Sora flood in Železniki on the 18th of September 2007

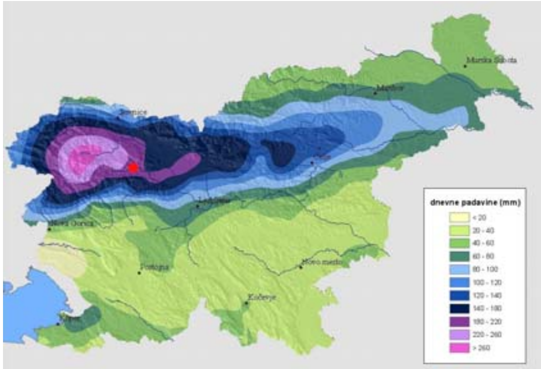


Figure 47. Daily precipitation measured at 6:00 UTC on the 19th of September 2007

Železniki is a small town, located in north-western part of Slovenia in a relatively narrow valley of the Sora River, the town has an elevation of 475m asl and it is surrounded by hills. The area is known for its abundant precipitations, and extreme precipitation is not rare. The mean annual precipitation is 1883 mm (reference period 1961–1990). Autumn precipitation is the most abundant (mean autumn precipitation is 551 mm), but daily maximum precipitation around 100 mm is possible in all months of the year. At 7 o'clock a.m. in Železniki, on the 19th of September 2007, 197 mm precipitation was measured for a 24 hours accumulation period. This amount exceeds by 40 mm the monthly mean value for September. Statistically, this event has a return period of more than a hundred years. The meteorological stations north-eastern from Železniki got even more precipitation: Dražgoše 216 mm, Davča 228 mm, Zgornja Sorica 233 mm, Bohinjska Češnjica 230 mm, Kneške Ravne 320 mm, ... all in just 24 hours.

Meteorological station in Železniki was established in 1896 as a station with precipitation measurements. From 1936 till nowadays the station has had the same location. Unfortunately, the meteorological logbooks from 1896 till 1923 are lost; and for this period we have only statistical reports – Jahrbücher – with monthly and annual values of precipitation. The data are digitised from 1930 on. The data from period 1923–1930 has to be digitised as the meteorological station of Železniki has not been chosen for digitising during FORALPS project.

This extreme event shows that long time series are important for:

- knowledge of extreme events,
- for prediction of extreme events and its magnitude,
- for calculation of return periods; with short time series the return period is over estimated: using Gumbel method on data from 1930–2007 the return period for Železniki extreme event is 1717 years ,
- tracing the climate variability or change.

4.3.3. Homogenisation of maximum seasonal total snow depth on Kredarica

Information about snow depth in the mountains is especially important for tourists, mountaineers and in the last years also for climatologists. Since EARS has only one single station above 2000m asl, it is necessary to have at least a more or less homogenous series; otherwise it is hard or even impossible to evaluate different seasons according to snow depth.

Systematic meteorological measurements started at Kredarica, at 2514m asl, in 1954. The station lies on the ridge and next to Triglav, our highest mountain (2864m asl) and next to the best known glacier in Slovenia – Triglav glacier. Wind blowing around these obstacles makes measurements of precipitation, particularly snow, very difficult. Snow drifts occur frequently and consequently snow depth at one place can change significantly and quickly even in periods of cold and dry weather. Observers take daily measurements at few places and also take into account weather situation before obtaining a representative value of total and fresh snow depth. Unfortunately this technique has changed in the past and consequently we have discovered a prominent jump in the values of data series of total snow depth.

As mentioned before, precipitation measurements also greatly depend on weather situation, so we decided to use data from nearby stations in alpine valleys where measurement errors due to weather are expected to be much smaller. After some trials we found appropriate predictors to homogenise the series of maximum seasonal snow depth. Field measurements of snow load in the vicinity of Kredarica have shown strong dependence of maximum seasonal snow depth on the precipitation sum, since the average snow density at the time of maximum depth is quite constant from year to year. Based on this result, we have chosen the average sum of precipitation in the winter time (from November through April) at three stations (Bohinjska Bistrica, Mojstrana, Trenta) as the predictor for the maximum snow depth.

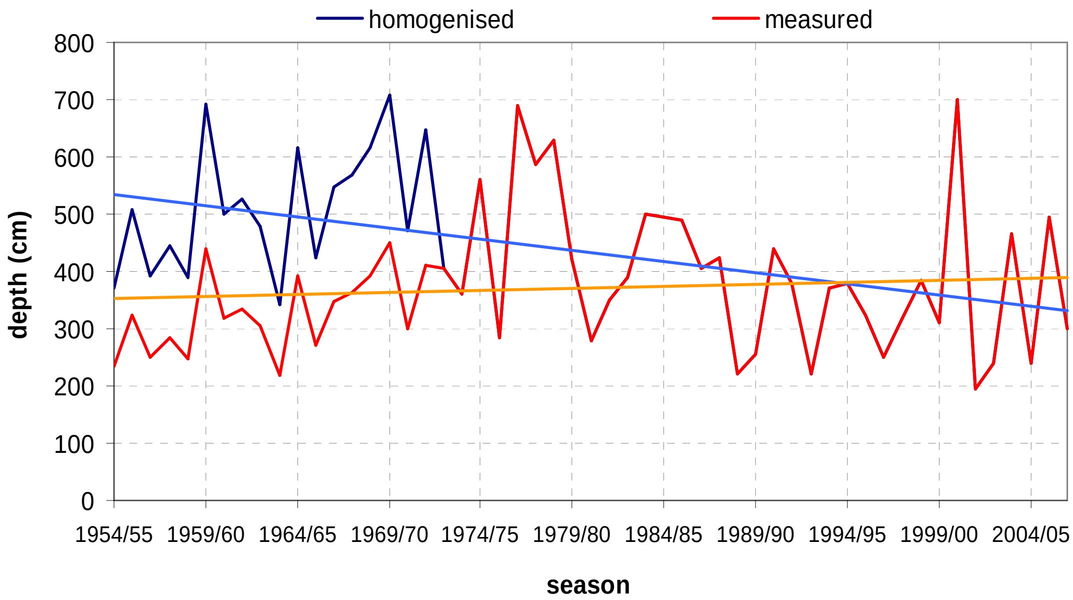


Figure 48. Series of original and homogenised maximum seasonal snow depth at Kredarica. The linear trend for both series is also shown.

The blue line on Figure 48 reveals a significant change in the ratio after the season 1971/72. The jump can be explained by metadata – measurement technique changed with the arrival of a new observer. Year-to-year fluctuations seen on Figure 48 are mostly related to very mild winters (frequent in the last two decades), which indicate the large impact of winter temperature on snow depth evolution. Therefore we decided to create two sets of seasons, for the period before and after the inhomogeneity, with similar climate statistics (sum of precipitation, average temperature). The average ratio was then calculated for both sets and divided to obtain a correction factor. This factor was applied to the period before inhomogeneity and results are shown by red line on Figure 48. The correction results in an increase of maximum snow depth of 57 %. This has an enormous impact on the calculated linear trend, which becomes obviously negative after the homogenisation procedure (Figure 48). The results were confirmed by observers in the 50's and 60's which claim that winters in this period were mostly severe and with abundant snow.

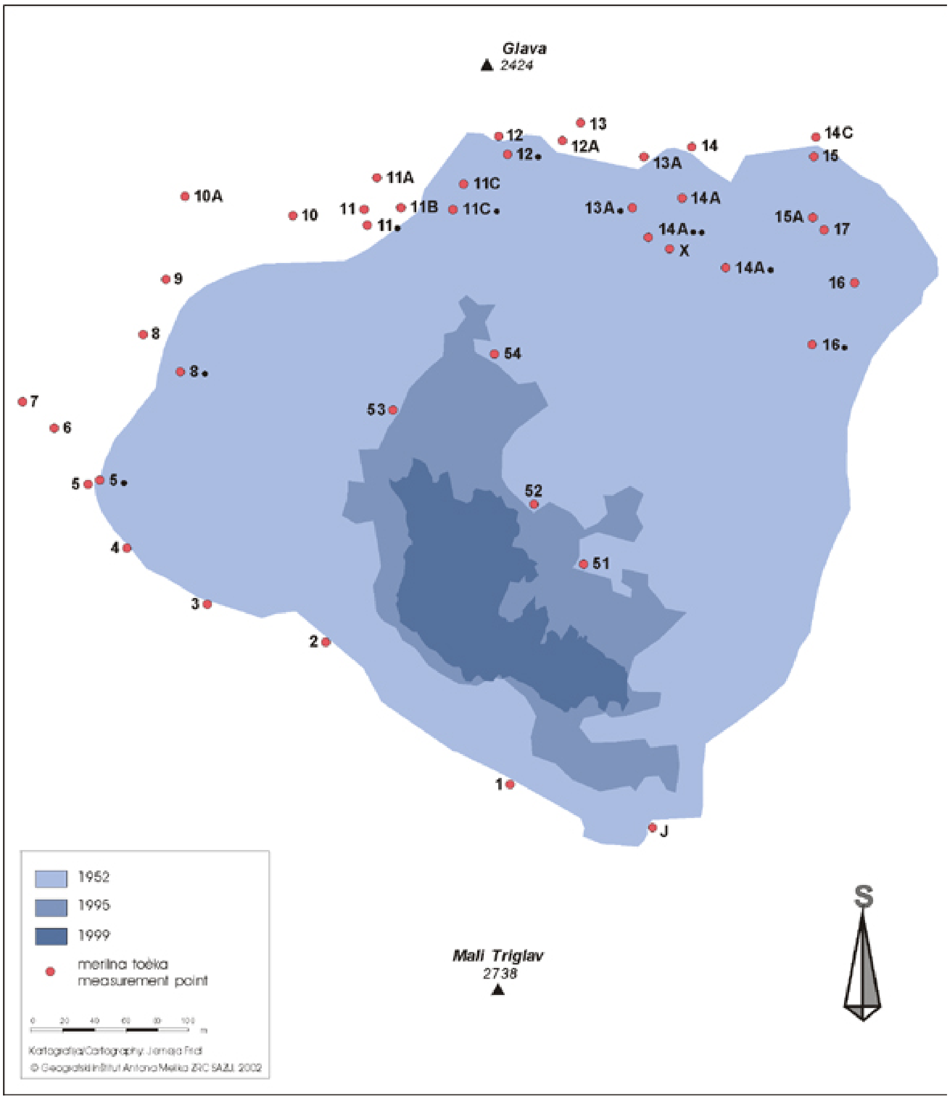


Figure 49. The area of Triglav glacier from 1952 to 1999

Trends of homogenised snow depth data along with trends of other meteorological parameters at Kredarica clearly show the reason for the reduction of Triglav glacier. At the end of 19th century the glacier's surface measured 45 ha, in year 1946 its surface was reduced to 15 ha, and in 1994 its surface was 4 ha. One year later (1995) the surface of the glacier measured 3,03 ha and in 2003 it was only 0,7 ha. Nowadays it can hardly be called a glacier. The glacier's surface has been constantly reducing since the end of the 19th century.

4.4. *UniTN*

In the course of FORALPS WP5 activities, Trento University provided a typical example of how it is possible to explore regional climate change with a study for the

Fiemme Valley. The Fiemme Valley is one of the most remarkable valleys in the north-eastern part of Trentino, delimited northward by the Dolomites and furrowed by the Avisio River, a tributary of the Adige River. Various weather stations were installed at the main centres of the valley at the end of the 19th century. In the work here presented (see Appendix 7: Reconstruction and analysis of the temperature and precipitation series of Fiemme Valley by Michele Tarolli et al.,) the series of temperature and precipitation from four stations in the above centres, namely Predazzo, Cavalese, Paneveggio and Passo Rolle, have been analysed. Data obtained from hydrological yearbooks were collected and minor gaps filled by means of suitable correlation with reference series (Trento, Bolzano/Bozen, Riva del Garda, Rovereto, Bressanone/Brixen, Belluno, Innsbruck, Mantova and Monte Maria/Marienberg). Outliers have been removed after careful check. The Standard Normal Homogeneity Test has been applied and inhomogeneities detected and removed. The resulting series display a clear tendency towards increasing temperature, whereas the identification of clear trends in precipitation regimes is questionable.

5. Outlook

5.1.ZAMG-W

The new digitised FORALPS data have extended the possibilities for further research on climate change and variability. This includes studies on methods as well as climate impact studies.

Within the next years new homogenisation tools will by released by an international COST activity ES0601 – Advances in homogenisation methods on climate series: an integrated approach. These tools can be applied to the now “softly homogenised” FORALPS data.

Climate change shows its impact nearly everywhere and no area is assured of being exempt. As climate change cannot be stopped in the near future, adaptation measures have to be planned. FORALPS temperature and precipitation data will contribute to the necessary impact studies in the field of:

- agriculture and forestry – droughts and dry spells, diffusion of pests, changes in vegetation periods and shifts of vegetation borders, phonological studies
- extreme events (heavy rain and floods, avalanches, landslides)
- energy consumption – heating and/or cooling
- tourism – risk in winter and summer
- health – diseases
- Change in the landscape and in land-use, permafrost, glaciers, etc.

5.2.EARS

Studying climate variability and change the need emerged for high quality and long datasets (validated, controlled and homogenised). Collecting these datasets is a time-demanding work and needs extensive resources. This is the reason that the progress of data recovery is very slow. In the framework of WP5 in FORALPS project EARS mobilised additional resources for data rescue and recovery activities. Several data and metadata sets were digitised for the existing observation period. These were validated and homogenised and, as such, are of very high value for a wide scientific and economic community (climate change adaptation, hydrology, energy demand, civil engineering, etc.). However, many data sets still need to be digitised, validated and homogenised.

There is a need for higher spatial density of long data sets for detailed climate variability analysis. Moreover, for extreme weather analysis longer data sets (with adequate spatial density) are essential. There is still much potential in non-digitised data stored in paper archives, which could be used to improve the spatial density of long data series. With a higher spatial density of long data series it would be possible to calculate high resolution maps, which could be the basis for risk map calculation. The demand for risk maps is growing, and due to their time-demanding production process, EARS could not meet all end-users' requirements. Requests from environment protection and management, adaptation policy makers, agronomy and energy sector are above what we are currently able to produce with present data density. Longer and denser data sets would also improve reliability of climate scenarios, while results of downscaling process highly depend on quality and density of measured data sets.

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7. Project Related Presentations and Dissemination of Results

7.1.Organised Partner Workshops

- ZAMG-W: Workshop: 9.08.2007 bis 10.08.2007 zum Homogenisieren von klimatologischen Zeitreihen auf Monatsbasis mit Unterstützung des Softwarepakets HOCLIS2

7.2.Participation in Conferences with oral presentations or posters

- Andrighetti, M., Rampanelli, G. and Zardi, D., Reconstruction and climatological analysis of the temperature series of Verona (1741-2006), Oral presentation at the 29th International Conference on Alpine Meteorology (ICAM2007), Chambéry, France, 4-8 June 2007 .
- Auer I, Korus E. 2005. The Variability of Heat Waves and Dry Spells in the flat and mountainous Regions of Austria, Poster Presentation for ICAM/MAP 2005, 23-27 May 2005, Zadar, Croatia..
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- Auer I, Böhm R, Jurkovic A, Korus E. 2006. Climate Variability in the Eastern Alps presented by selected Climate Indices. Oral presentation at 1st FORALPS Conference, Ljubljana 6 September 2006.
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- Böhm R. 2007. Climate Reconstructions in the instrumental period: Problems and solutions for the Greater Alpine Region. Oral Presentation held at the 2nd FORALPS Conference in Salzburg, 28. 11. 2007
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7.3.Publications –papers – Conference Proceedings

On the internet
http://www.arso.gov.si/vreme/poro%c4%8dila%20in%20projekti/foralps.html ,

- Foralps – Interreg projekt, 2007, Environmetal Agency of the Republic of Slovenia, Ljubljana, leaflet
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- Appendix 5: A method to estimate daily maxima and minima based on single daily air temperature readings: by Michele Andrighetti, Massimiliano de Franceschi, Dino Zardi (Atmospheric Physics Group, Department of Civil and Environmental Engineering, University of Trento)

to 4. Examples for FORALPS Data Applications and Data Analyses

- Appendix 6: Interpolation and Regionalization of daily snow depth datasets for Austria – Comparison of two time slices (1896-1916 vs. 1980 – 2000): by Anita Jurkovic, Ingeborg Auer and Reinhard Böhm (Zentralanstalt für Meteorologie und Geodynamik, Wien).
- Appendix 7: Reconstruction and analysis of the temperature and precipitation series of Fiemme Valley: by Michele Tarolli (1), Roberto Rea (2), Dino Zardi (3) (1 Provincia Autonoma of Trento, 2 Comune of Campitello of Fassa, 3 University of Trento)

List of acronyms

AWS	Automatic Weather station
ECA&D	European Climate Assessment & Dataset: for more information contact: http://eca.knmi.nl/
EMULATE	European and North Atlantic daily to MULtidecadal climATE variability. EU Research project - Contract no: EVK2-CT-2002-00161 EMULATE, November 2002 to October 2005, Co-ordinated by Prof. Phil Jones, Climatic Research Unit
WMO	World Meteorological Organization, for more information contact: http://www.wmo.ch/pages/index_en.html

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